Carderock Division
Naval Surface Warfare Center
Bethesda, MD 20084–5000

CARDEROCKDIV–93/007 June 1993

Communication and Information Systems Department
Test and Evaluation Report

Results of a Joint Navy/Air Force Operational Test to Evaluate USAF Integrated Maintenance Information Systems (IMIS) Interactive Electronic Technical Manual (IETM) Technology Applied to the F/A–18 Aircraft

by
Mark T. Kramer (Carderock Division, NSWC)
and
Theodore J. Post
Samuel C. Rainey (Scientific Management Associates, Inc.)

Results of a Joint Navy/Air Force Operational Test to Evaluate USAF Integrated Maintenance Information Systems (IMIS) Interactive Electronic Technical Manual (IETM) Technology Applied to the F/A–18 Aircraft

CARDEROCKDIV–93/007

THIS PAGE INTENTIONALLY LEFT BLANK

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

- **1a. REPORT SECURITY CLASSIFICATION:** UNCLASSIFIED
- **1b. RESTRICTIVE MARKINGS:**
- **2a. SECURITY CLASSIFICATION AUTHORITY:**
- **2b. DECLASSIFICATION/DOWNGRADING SCHEDULE:**
- **3. DISTRIBUTION/AVAILABILITY OF REPORT:** Approved for public release; distribution is unlimited.
- **4. PERFORMING ORGANIZATION REPORT NUMBER(S):** CARDEROCKDIV-93/007
- **5. MONITORING ORGANIZATION REPORT NUMBER(S):**
- **6a. NAME OF PERFORMING ORGANIZATION:** Carderock Division, Naval Surface Warfare Center
- **6b. OFFICE SYMBOL (If applicable):** Code 182
- **6c. ADDRESS (City, State, and ZIP Code):** Communication & Information Systems Department, Carderock Division, NSWC, Bethesda, Maryland 20084–5000
- **7a. NAME OF MONITORING ORGANIZATION:**
- **7b. ADDRESS (City, State, and ZIP Code):**
- **8a. NAME OF FUNDING/SPONSORING ORGANIZATION:** Naval Air Systems Command
- **8b. OFFICE SYMBOL (If applicable):** 41144
- **8c. ADDRESS (City, State, and ZIP Code):** Naval Air Systems Command, Washington, DC 20361–0001
- **9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER:**
- **10. SOURCE OF FUNDING NUMBERS:**

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.

- **11. TITLE (Include Security Classification):** Results of a Joint Navy/Air Force Test to Evaluate USAF Integrated Maintenance Information System (IMIS) Interactive Electronic Technical Manual (IETM) Technology Applied to the F/A–18 Aircraft
- **12. PERSONAL AUTHOR(S):** Kramer, Mark T. (CDNSWC), Post, Theodore J., Rainey, and Samuel C. (Scientific Management Associates, Inc.)
- **13a. TYPE OF REPORT:** Final
- **13b. TIME COVERED:** FROM 891001 TO 911001
- **14. DATE OF REPORT (YEAR, MONTH, DAY):** 1993 June 14
- **15. PAGE COUNT:** 143
- **16. SUPPLEMENTARY NOTATION:**

17. COSATI CODES

FIELD	GROUP	SUB-GROUP

- **18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number):** Automated Technical Manuals; Interactive Electronic Technical Manuals (IETMs); Portable Maintenance Aid; Portable Delivery Device; Integrated Maintenance Information System (IMIS); F/A–18 Aircratf

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

In a joint effort, the U.S. Navy and Air Force have tested under operational conditions a series of improved techniques developed under the Air Force Integrated Maintenance Information System (IMIS) program for delivering maintenance technical information to squadron technicians. These improvements included use of a portable maintenance aid (PMA) for technical information display. In this test, carried out in an F/A–18 fighter squadron at Marine Corps Air Station, Beaufort, South Carolina, each of 16 technicians performed six fault–isolation tasks, three supported by an Interactive Electronic Technical Manual (IETM) displayed on a PMA, and three supported by conventional paper–based work package (WP) technical manual (TM). This report presents a comparison of technician performance supported by the ITEM/PMA combination with performance using conventional paper TMs. The performance data collected during the test showed considerable reduction in performance times for complex multiple fault isolations and maintenance errors, when technicians used the IETM/PMA combination. Also, technician–preference data based on questionnaires, showed strong support for virtually all IETM/PMA features. Technicians also made suggestions for *(Continued on reverse side)*

- **20. DISTRIBUTION/AVAILABILITY OF ABSTRACT:** ☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT ☐ DTIC USERS
- **21. ABSTRACT SECURITY CLASSIFICATION:** UNCLASSIFIED
- **22a. NAME OF RESPONSIBLE INDIVIDUAL:** Joseph A. Fuller
- **22b. TELEPHONE (Include Area Code):** (301) 227–1358
- **22c. OFFICE SYMBOL:** Code 182

DD FORM 1473, JUN 86 *Previous editions are obsolete.*

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

Block 19. ***(Continued)***

improving the IETM and the PMA. The test results have been provided to both Services as one basis for evaluating and improving these IMIS technologies; specifically, (1) the specifically developed PMA; (2) preparation and automation of the IETM technical information by auotmated methods based on initial construction of an IETM data base, IETMDB; (3) the IMIS Presentation System (PS); (4) on-ground fault isolation using data from aircraft Built-in Test Equipment (BITE) coupled directly to the PMA through a 1553 bus; (5) the IMIS Diagnostic Module (DM), and (6) the IMIS Human Computer Interface (HCI) module. The IETMDB and the IETM technical information were constructed generally in accordance with the new DoD Specifications MIL-D-87269 and MIL-M-87268, respectively.

CONTENTS

Contents (Continued)

Contents (Continued)

TABLES

FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK

ACKNOWLEDGEMENTS

Acknowledgements need to be made to the many people who contributed to this project. Mr. Shawn Magill, Code 411, Naval Air Systems Command, provided direction as the monitor for the sponsoring agency. The Carderock Division, Naval Surface Warfare Center, (CDNSWC) was designated as the research center responsible for the project. Mr. Joseph Fuller, Code 1223, was the senior official representing CDNSWC. Mr. John Junod, CDNSWC, was the project manager throughout most of the planning stages. He provided the all-important liaison with Dr. Donald Thomas, the leader of the Air Force's effort at Armstrong Laboratories/Human Resources Group (AL/HRGO). 2LT Eric Carlson, AL/HRGO, served as on-site Test Director. Dr. Robert Smillie of the Naval Command Control and Ocean Surveillance Center (NCC&OSC) provided technical input throughout the project, especially in the areas of experimental design and data analysis.

ABSTRACT

In a joint effort, the U.S. Navy and the Air Force have tested under operational conditions a series of improved techniques developed under the Air Force Integrated Maintenance Information System (IMIS) program for delivering maintenance Technical Information to squadron Technicians. These improvements included use of a Portable Maintenance Aid (PMA) for Technical Information display. In this test, carried out in an F/A-18 fighter squadron at Marine Corps Air Station, Beaufort, South Carolina, each of 16 Technicians performed six Fault-Isolation tasks, three supported by an Interactive Electronic Technical Manual (IETM) displayed on a PMA, and three supported by a conventional paper-based Work Package (WP) Technical Manual. This report presents a comparison of Technician performance supported by the IETM/PMA combination with performance using conventional paper Technical Manuals. The performance data collected during the test showed considerable reduction in performance times for complex, multiple Faults Isolations, and reduction of maintenance errors, when Technicians used the IETM/PMA combination. Also, Technician-preference data based on questionnaires showed strong support for virtually all IETM/PMA features. Technicians also made suggestions for improving the IETM and the PMA. The test results have been provided to both Services as one basis for evaluating and improving these IMIS technologies; specifically, (1) the specially developed PMA; (2) preparation of the IETM Technical Information by automated methods based on initial construction of an IETM data base (IETMDB); (3) The IMIS Presentation System (PS); (4) on-ground Fault Isolation using data from aircraft Built-In Test Equipment (BITE) coupled directly to the PMA through a 1553 bus; (5) the IMIS Diagnostic Module (DM), and (6) the IMIS Human Computer Interface (HCI) module. The IETMDB and the IETM Technical Information were constructed generally in accordance with the new DOD Specifications MIL-D-87269 and MIL-M-87268, respectively.

ADMINISTRATIVE INFORMATION

The work presented in this report was accomplished under the direction of the Carderock Division, Naval Surface Warfare Center (formerly the David Taylor Research Center) under Job Order JO 1-1223-103 funded by NAVAIR 411 under AIRTASK A4114114-0104-1411400001.

1.0 TEST SUMMARY

1.1 TEST OVERVIEW

In a joint effort, the Navy and the Air Force have carried out an operational test of a series of technological improvements developed by the US Air Force under its Integrated Maintenance Information System (IMIS) Program for delivering maintenance Technical Information to technicians. These innovations consisted of:

a. Creation of maintenance Technical Information through use of an Interactive Electronic Technical Manual Data Base (IETMDB) meeting the general requirements of the newly developed MIL-D-87269; ***Data Base, Revisable Interactive Electronic Technical Manuals, for the Support of***, 20 Nov 1992 (ref. 1).

b. Conversion of the Technical Information in the IETMDB to a form suitable for viewing by the end user on a Portable Maintenance Aid (PMA) through use of the IMIS PS (Presentation System) software housed in the PMA itself. (Note that the IMIS term PMA, which will be used throughout this report, is synonymous with the term Portable Electronic Delivery Device (PEDD) used in the U.S. Naval Air Systems Command.)

c. The field use of PMAs for Fault Isolation.

d. The use of direct interaction between aircraft Built-In Test Equipment (BITE) and the PMA, through a 1553 bus to facilitate on-ground Fault Isolation. The on-board data were integrated in the PMA by the IMIS Diagnostic Module (DM).

e. The use of the HCI (Human Computer Interface) model of IMIS for presentation of the Technical Information, which is generally in accordance with the newly issued MIL-M-87268; ***Manuals, Interactive Electronic Technical: General Content, Style, Format, and User-Interaction Requirements***, 20 Nov 1992 (ref. 2).

Each Technician performed six Fault-Isolation tasks, three supported by an Interactive Electronic Technical Manual displayed on a developmental Portable Maintenance Aid (IETM/PMA) and three supported by the squadron's conventional paper-based Work Package (WP) Technical Manuals. The IETM/PMA combination represented the most up-to-date technology of the Air Force's Integrated Maintenance Information System (IMIS) Program. Tests were made using the Flight Control System of

the Navy F/A-18 aircraft. The test facility and test personnel were provided by the USMC Fighter Squadron VMFA-312, Marine Corps Air Station, Beaufort, SC. After a Pretest (or Pilot-test) phase designed to identify and resolve logistics, technical, or other problems, the Test was conducted during a three-week period from 31 May 1992 to 19 June 1992.

1.2 PREPARATION OF TEST MATERIALS

The IETMs used were based on IETMDB material (F/A-18 maintenance data) created by McDonnell Douglas Aircraft Company (MCAIR). The Technical Information in the IETMDB was extracted and converted to IETM format by IMIS Presentation System software hosted in the PMAs, which were specifically constructed for this Test by the Air Force Armstrong Laboratory, Human Resources Directorate (AL/HRGO). The Carderock Division, Naval Surface Warfare Center, monitored the authoring process and the resulting IETM product. The extraction, compiling, and formatting processes required were accomplished by a largely automated IMIS technique called the Presentation System (PS).

1.3 TEST OBJECTIVE

The objective of the test was to evaluate the effectiveness of several IMIS modules developed for the preparation and display of IETMs as compared with paper-based Technical Manuals. Specifically, the IMIS modules evaluated included:

a. A data base prepared for the F/A-18 in accordance with the USAF Content Data Model (CDM), a technique which forms the basis of ref. 1.

b. A new lightweight Portable Maintenance Aid (PMA) built by AL/HRGO under the IMIS program.

c. Improvement in Fault-Isolation effectiveness resulting from direct interaction between the PMA and the F/A-18's Built-In Test capabilities via the 1553 multiplex bus interfaced with the IMIS Diagnostics Module (DM).

d. New techniques for developing and displaying troubleshooting instructions, i.e., instructions selected dynamically by a presentation system hosted in the PMA, based on previous test outcomes and test-candidate characteristics such as times-to-test and failure rates of the affected components.

e. Computer-assisted completion of maintenance records [e.g., Visual Information Display System/Maintenance Action Form (VIDS/MAF), the NAVAIR maintenance control and reporting form].

1.4 TEST STRUCTURE

The test compared performances of Technicians working with the IETM/PMA combination to performances of Technicians working with the existing F/A-18 paper-based Work Package (WP) Technical Manuals. Sixteen Marine Corps Technicians (with Electrician or Communication/Radar/Navigation MOSs) performed the work. Half of the Technicians were experienced and half, inexperienced. After an initial indoctrination session, each Technician was asked to perform six Fault-Isolation tasks, three guided by IETM/PMA-presented TI and three guided by paper-based F/A-18 work-package TMs (i.e., a total of 96 individual tests). Each of the six Fault-Isolation tasks was divided into a number of sequential Intervals. The faults were of three significantly different types.

Data collectors recorded performance times and errors for each Interval of the participants' performances, and solicited Technicians' opinions as to effectiveness of various features of the IETM/PMA combination.

1.5 TEST RESULTS

IETM technological innovations tested in the field worked satisfactorily in all cases. Technicians were able to perform the troubleshooting tasks assigned in a shorter time with the IETM/PMA combination than with the existing paper-based Technical Manuals (with isolated exceptions). Performance benefits were particularly noticeable with regard to inexperienced Technicians, whose performance was brought to a level approximating that of the experienced Technicians, a result indicating that the advent of IETMs into the squadrons could significantly reduce the requirements for training and could result in a more effective use of inexperienced maintenance Technicians. Fault-Isolation errors were few. All data are presented in detail in section 4 and evaluated in section 5.

In response to questionnaire based interviews, Technicians:

- Showed preference for virtually all of the IETM/PMA features, and

- Provided a number of suggestions for further enhancement of the IETM/PMA combination.

1.6 TEST CONCLUSIONS

All phases of the Joint Navy/AF F/A-18 tests are considered to have been successful in that they:

a. Showed that the extensive automation applied to procedures for creating and displaying IETMs on PMAs produced improvements in Technician performance (over performance with paper TMs) equivalent to that produced by IETMs which had been prepared entirely by a human author.

b. Provided detailed guidance for improvement of the IMIS developmental procedures and modules tested, both as a result of the quantitative test data (e.g., performance times) and as a result of an extensive set of Technicians' evaluations.

1.7 STRUCTURE OF TEST REPORT

Section 2 presents background information leading to the Test. Section 3 describes the Test methodology. Section 4 presents the results attained from the tests, particularly performance time and performance errors. Section 5 discusses the significance of these results. Section 6 presents Conclusions and Recommendations. Appendix A contains a detailed summary of Technicians' Comments concerning the IETM/PMA combinations. Appendixes B through E show the forms used by test personnel to obtain Technician Responses. Appendix F presents sample IETM/PMA frames.

2.0 TEST BACKGROUND

2.1 BACKGROUND

2.1.1 The Computer-aided Acquisition and Logistic Support (CALS) Initiative

Under the CALS Initiative, the Department of Defense is moving to apply integrated computer technology to support the development and maintenance of its weapon systems. In support of this thrust, the USAF Armstrong Laboratory, Human Resources Directorate (AL/HRGO) and the Carderock Division of the Naval Surface Warfare Center (CDNSWC) have been performing coördinated RDT&E to improve the presentation of Technical Information to enlisted Technicians engaged in maintenance of weapon systems through the use of interactive electronic display.

2.1.2 IETM Development Research History

Since the mid-1960s, the military Services have sought to improve the overall quality, management, and delivery of military Technical Information in all of its aspects. Initial efforts concentrated on developing improved paper Technical Manuals. Since the early 1980s, the emphasis of the effort has shifted to the application of computer technology for the storage, control, and presentation of maintenance, system-operation, training, and other forms of logistic-support Technical Information. All Services have established on-going programs to develop and apply this technology. Table 1 lists the major operational tests of these endeavors to date. (See References for complete citations).

The advantages and deficiencies of the TI preparation and delivery approaches noted during these tests, together with recent technological advances, have provided the basis for developing the next generation of electronic delivery systems. Most recently, AL/HRGO and CDNSWC have collaborated on the field test of an IETM/PMA combination using as a test bed the Flight Control System (FCS) of the Navy F/A-18 aircraft. The advantages and deficiencies of previous systems are summarized below, followed by a list of the technological features which were designed into the IETM/PMA combination in an effort to overcome the deficiencies noted.

TABLE 1.

ELECTRONIC DELIVERY SYSTEM TESTS
PRIOR TO CURRENT USAF/USN F/A-18 TEST

PROJECT TITLE	PERFORMING AGENCY	DATE OF T&E	TEST VEHICLE
Computer-based Maintenance Aids System (CMAS-I) [ref. 3]	Air Force Human Resources Laboratory (AFHRL)	January 1985	APX 64 IFF Transponder Set
Navy Technical Information Presentation System (NTIPS-I) [ref. 4]	David Taylor Research Center (DTRC)	October 1986	F-14A Rudder Manual Trim System (RMTS)
CMAS -II [refs. 3,5]	AFHRL/Navy Personnel Research and Development Center (NPRDC)	December 1986	APX 64 (V) IFF Transponder Set
NTIPS II [ref. 6]	DTRC	April 1987	AN/SPA-25D Radar Repeater Set
Personal Electronic Aid for Maintenance (PEAM) [ref. 7]	U.S. Army ARI	March 1989	
Portable Computer Maintenance Aids System (PCMAS) [ref. 8]	AFHRL	May 1989	F-16 Fire Control Radar

2.1.2.1 Advantages of Electronic-Display Approaches Shown by Tests

- The optimal association of text and graphics on the screen is much easier for the technician to comprehend than the current paper-based formats.
- Technical Manuals in electronic form require considerably less manpower to update than their paper counterparts.
- Software linking between screens allows the technician to gain direct short-term access to related pieces of information. The same access through cross-referencing in paper Manuals is much more time-consuming and tedious.
- Interactive troubleshooting guidance contained in electronic delivery systems is more effective than its counterparts in conventional paper Manuals.

2.1.2.2 Deficiencies Reported During Previous Tests

- The pre-established form of the troubleshooting instructions in earlier tests restricted the Technicians' use of their experience and knowledge in streamlining a Fault-Isolation procedure. Fault-Isolation procedures using feedback from previous maintenance actions (e.g., actual failure-rate data) can increase the effectiveness of such procedures.
- Many of the devices used to display the TI, and especially their user interfaces, were off-the-shelf commercial items, not designed for maintenance applications and less than optimum in human-factors design. In cases where special devices were designed, bulk and weight were problems.
- Most future and many current weapon systems include Built-In Test (BIT) capability, yet only the PCMAS device used in the F-16 test (ref. 8) had a capability which allowed the Technician to use his display device to interact directly with BIT. Such an interaction provides a potential for improving the timeliness and accuracy of diagnostics.
- The maintenance process includes a substantial amount of paperwork which lends itself to computer-assisted preparation. However, previous programs had not fully tested this potential application.
- Graphics were in general of poor quality. Display software was frequently inadequate (e.g., requiring unacceptable time to associate the required text and graphics, and to present successive frames to the user).

2.1.2.3 Technological Advances

As repeated field tests have refined both operational requirements for IETMs and an understanding of the effectiveness and deficiencies of proposed approaches, the Navy and the Air Force have continued

developmental and evaluational efforts in IETM technology. The IMIS program of the USAF Armstrong Laboratory (AL/HRGO) [Refs. 8,9,10] continued the efforts started under the CMAS and PCMAS projects with the purpose of exploiting recent technological advances. The products developed by applying these advances included the following:

- **Portable Maintenance Aid (PMA).** AL/HRGO developed a portable display device for the F/A-18 test consisting of a special-purpose portable computer specifically designed to support maintenance on the flightline. A key feature of the device is its transflexive, high-resolution, Liquid-Crystal Display (LCD) usable in a range of ambient light from bright sunlight to total darkness. Specifications for the PMA are given in Table 2. The keyboard and screen layout are shown in Figure 1.

- **Diagnostic Module (DM).** [ref. 10] The DM is designed to use Technical Information extracted from the aircraft's BIT via the 1553 data bus, and to integrate this information with system Technical Information (e.g., signal-flow information), symptom-fault relationships, test times, rectification times, and component failure rates. From these data, the DM computes a recommended procedure for isolating an observed fault. The Technician may follow the recommended procedure or he may rely on his experience to select one of the listed alternative strategies. Also, the DM has the capability of handling cases involving multiple faults.

- **Content Data Model (CDM).** The CDM is a hierarchical data base structure similar to the "topdown breakdown" approach used to organize parts and pieces of a weapon system. The CDM offers an orderly structure for electronically storing and exchanging software-system independent digital representations of the system data upon which the IETM is constructed. From this data base (the IETMDB), it is possible to extract the data and display it on any of several display devices, provided that a suitable Presentation System (PS) is available to establish the proper information sequencing and arrangement. The test was intended to assess the suitability of a portion of the F/A-18 data base constructed in accordance with the MIL-D-87269 revisable data base Specification. [ref. 1] (Note that this evaluation, involving the effectiveness of the IETMDB as an interim measure in preparing the IETM, was not part of the field evaluation described in this report, which tested only the final IETM product. The IETMDB evaluation is being reported separately by Armstrong Laboratory.)

- **Presentation System (PS).** The IMIS PS is a software package that extracts data from the IETMDB, organizes it, and provides the proper commands so that it can be viewed on specific display devices; in this case, the IMIS PMA. In addition, it maintains records of maintenance actions taken and automatically completes forms to report these actions. An evaluation of the effectiveness of the PS in providing IETM Technical Information is being performed by Armstrong Laboratory.

TABLE 2.

IMIS PMA SPECIFICATIONS

CPU	Motorola 68020-based hybrid
Size	9.5" x 10.5" x 2.5"
Case	Carbon-fiber composite
Weight	6 lbs
Display	Ovonics 6" x 8" monochrome active matrix, 640 x 480 resolution
Memory	6 MByte SRAM, 4 MByte FLASH PROM, 32 MByte removable memory cartridge
Graphics	Intel 87871-based hybrid
Interfaces	MIL-STD 1553, RS 232C, 1.3 MHs channel hopping radio
Power Supply	16.5 Volt Yardney Silvercell battery pack (4 hour), 15 Volt DC external output
Operating System	Application software
Digital Multimeter	AC Volts, DC Volts, Ohms, autoranging

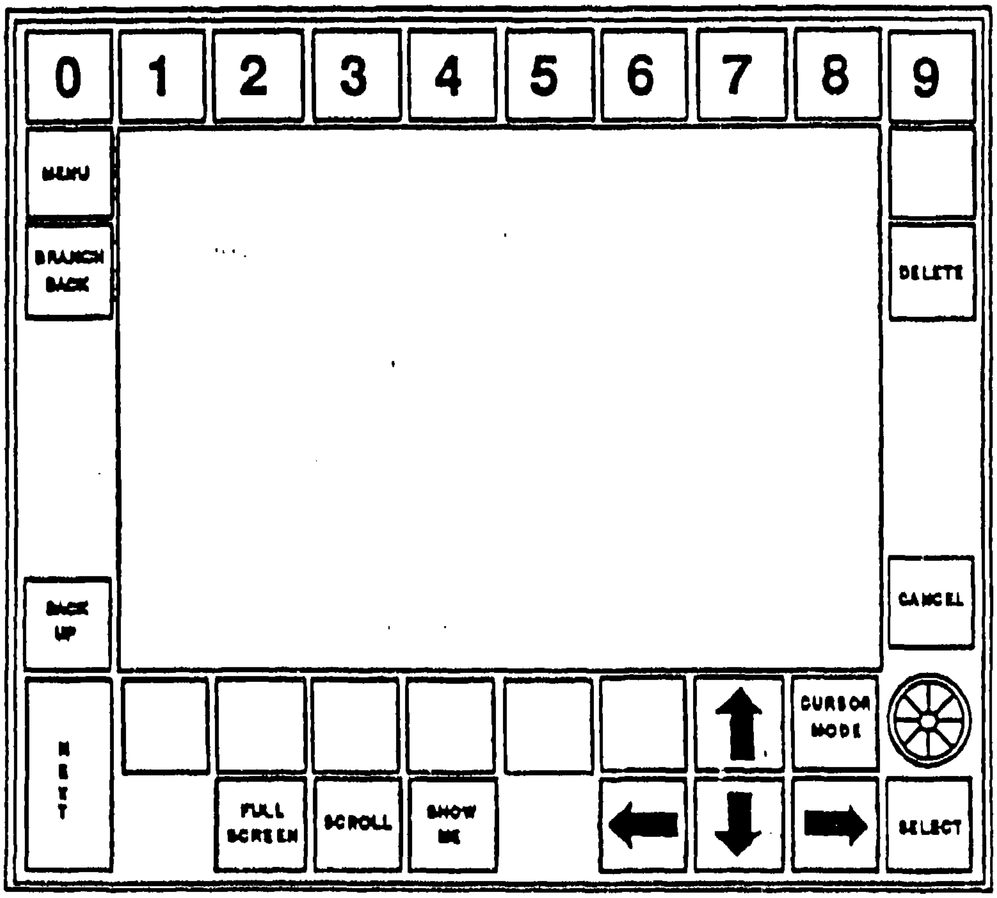


Figure 1 PMA Keyboard Interface.

- **Human Computer Interface (HCI).** The IMIS PMA, as designed and configured in accordance with the HCI, permits the rapid retrieval of desired Technical Information, including information via the 1553 bus from the aircraft's BIT. Because of the PMA's small size, input devices include only a limited keyboard (numbers, special-function keys, and programmable function keys) and a joystick. An adaptation of the Open Software Foundation methodology, the HCI uses the "aim and shoot" approach for information access and manipulation. The test was designed to evaluate the HCI by fielding an IETM/PMA combination constructed in accordance with MIL-M-87268 [ref. 2], which provides requirements for general content, style, format, and user-interaction features of IETMs. The HCI has been described in some detail in ref. 11.

2.1.3 The Interactive Electronic Technical Manual (IETM)

The term IETM [see ref. 12] has been defined, for example, in ref. 2, as follows:

> **A Technical Manual, prepared (authored) by a Contractor and delivered to the Government, or prepared by a Government activity, in digital form on a suitable medium, by means of an automated Authoring System; designed for electronic-screen display to an end user, and possessing the following three characteristics:**
>
> **a. The format and style of the presented information are optimized for screen presentation to assure maximum comprehension; that is, the presentation format is "frame-oriented", not "page-oriented".**
>
> **b. The elements of Technical Information constituting the TM are so interrelated that a user's access to the information he requires is facilitated to the greatest extent possible, and is achievable by a variety of paths.**
>
> **c. The computer-controlled TM-Display device can function interactively (as a result of user requests and information input) in providing procedural guidance, navigational directions, and supplemental information; and also in providing assistance in carrying out logistic-support functions supplemental to maintenance.**

Characteristics of such a presentation have been described, for example, in ref. 3, and general requirements are presented in MIL-M-87268 [ref. 2]. The HCI and the Presentation System of IMIS have been designed to present the required Technical Information to a technician in IETM form.

3.0 METHODOLOGY

3.1 GENERAL APPROACH

Although the test was carried out under normal squadron maintenance conditions to the extent possible, some minor changes to normal procedures were necessitated. These included:

a. Assignments were given to Technicians by test personnel rather than Maintenance Control and Work Center supervisors.

b. Communications with Supply were simulated by test personnel.

c. One Technician was asked to perform all of the work of an action instead of using the customary team approach.

d. External hydraulic power was used as compared with the usual practice of relying on aircraft hydraulic systems.

e. A technically qualified test supervisor stayed with the test Technicians to assure safety and to respond to any questions the test Technicians had.

3.2 TEST METHODOLOGY

In order to accomplish the Test objective (see section 1.3), the primary methodology of the Test was to compare (a) the effectiveness of Technicians' troubleshooting performance when using the specially prepared IETM/PMA combination, with (b) the effectiveness of their performance when using paper Technical Manuals to guide their efforts.

Specifically, the following testing was done:

a. With each type of Technical Manual, compare troubleshooting performance in terms of time on task, success in finding the fault, number of False Removals, and Procedural Errors.

b. Evaluate user preference for the IETM/PMA combination with respect to the paper TMs, stressing information access and presentation effectiveness. Solicit user suggestions with

regard to troubles experienced with, and proposed improvements for, the technological improvements tested. (These features are summarized in section 2.1.2.1.)

c. Evaluate the PMA design in accordance with Human Factors principles and user preferences.

d. Evaluate three principal maintenance-support capabilities of the IETM/PMA combination on the bases of troubleshooting performance measures and user preferences. These capabilities were:

   (1) The diagnostic interface of the IETM/PMA with the F/A-18 Built-In-Test Equipment (BITE) through the 1553 multiplex bus.

   (2) The automated completion of standard maintenance-action and reporting forms and parts-ordering requests.

   (3) The integrated display of diagnostic instructions, maintenance procedures, and schematic diagrams by means of a self-contained portable display device (the PMA).

3.3 TEST DESIGN

In the experimental design was a 2x2x3-factorial mixed design. The independent variables were:

Factor 1	The Technical Information Display approaches (two: IETM/PMA and Paper TM);
Factor 2	Experience levels of the Technicians (two: Experienced and Inexperienced);
Factor 3	The types of faults (three: Relay Faults, Cannot Duplicate "faults", and Multiple Faults. The fault types are described in section 3.4.1.). Each type of fault had two representative faults of equal complexity; i.e., six individual fault situations were used.

Factor 2 involved between-group comparisons; Factors 1 and 3 involved within-group comparisons.

Each of the 16 Technicians attempted three Fault Isolations using the IETM/PMA combination (one from each fault-type pair) and three Fault Isolations using the paper TMs (the remaining fault from each pair). From each experience-level group, four participants used the IETM/PMA combination first and four used the paper TM first. This counterbalancing eliminated the effects of learning bias and interference. Each Fault-Isolation procedure was performed an equal number of times with IETM/PMA and paper-TM

support; i.e., paper TMs were used for three Fault Isolations and the IETM/PMA combination was used for three different isolations. To avoid confusion and interference learning, one TM type was used for three consecutive Fault Isolations, then the other system was used for the next three. The faults assigned to the paper-TM tests and the IETM/PMA tests were randomized to eliminate undesirable learning effects either positive or negative.

To accommodate a total of eight participants in each experience group, two additional sequences were randomly selected in such a way that each Fault Isolation was attempted an equal number of times with each type of TM, and that each Fault-Isolation sequence within a pair was carried out an equal number of times. As a last precaution, the assignment of TM type to test Technicians was alternated between IETM/PMA-then-paper and paper-then-IETM/PMA. The effect of these assignment considerations resulted in the run schedule shown as Table 3.

3.4 FAULT DESCRIPTIONS

3.4.1 Faults

The Strike Aircraft Test Directorate at Naval Air Station (NAS) Patuxent River had evaluated a "Fault Insertion Program" for the Naval Air Systems Command [refs. 13 and 14]. The purpose of the project was to generate and exercise simulated faults as a means of testing the BIT capability of the F/A-18 FCS. A total of 188 faults were developed which could be "inserted" into the FCS through the use of a device referred to as a Breakout Box. A total of 34 additional faults were developed later. Four of the faults used in the F/A-18 IETM/PMA test were drawn from this pool of 222 faults. Three fault types were used as the basis for the test: two faults were chosen from each of three fault types.

TABLE 3

PARTICIPANT RUN SCHEDULE

Test Subjects	Type of Fault Sequence		Type of TM		
1	3 1 5	2 6 4	PMA	-	Paper
2	1 3 5	4 6 2	Paper	-	PMA
3	4 2 6	5 3 1	PMA	-	Paper
4	6 2 4	3 1 5	Paper	-	PMA
5	1 5 3	6 2 4	PMA	-	Paper
6	5 1 3	2 4 6	Paper	-	PMA
7	6 2 4	5 1 3	PMA	-	Paper
8	2 6 4	3 1 5	Paper	-	PMA
9	3 5 1	2 6 4	PMA	-	Paper
10	1 3 5	4 6 2	Paper	-	PMA
11	4 2 6	5 3 1	PMA	-	Paper
12	6 2 4	3 1 5	Paper	-	PMA
13	1 5 3	6 4 2	PMA	-	Paper
14	5 1 3	2 4 6	Paper	-	PMA
15	6 2 4	5 1 3	PMA	-	Paper
16	2 6 4	3 1 5	Paper	-	PMA

The three pairs of faults by type are:

a. Relay (Electrical) Faults (Faults 1 and 2).

Insertion of two defective relays which had failed while in service was used to represent these faults. The main characteristic of this fault set was several branchings in the Fault-Isolation procedure. The paper TM indicated branching by a two-column "go to" arrangement which directed the Technician to move to the next step or a step further downstream or upstream in the step sequence. The IETM/PMA required only simple keying actions to input test results and to display the next action. The two faults in this set involved:

1 Nose Wheel Steering Selector Valve

2 Left Wing Unlock Relay

b. Can Not Duplicate (CND) Faults (Faults 3 and 4).

Using the paper TM to isolate faults in this set required a Technician to watch a rapidly scrolling set of multi-digit numbers in a window of his Digital Display Indicator (DDI) and then, by referring to a chart in a different location in the TM, judge whether the numbers he had seen fell within the chart's acceptable range. The IETM/PMA combination fed the numbers into the PMA (via the 1553 interface bus) which performed an initial, automatic, assessment of the numbers. This pair of "faults" consisted of the Can Not Duplicate (CND) faults; i.e., the correct result of the Technicians' task was to indicate the absence of a fault. Thus, no faulty components were in fact present, real or simulated. However, the symptoms reported to the Technicians indicated faults in the following components:

3 Right Trailing Edge Flap

4 Left Stab Test

c. Multiple Faults (Faults 5 and 6).

Each fault of this fault type consisted of establishing a combined set of symptoms for two failed components. The insertion of these faults used the Breakout Box referred to earlier. In Fault Isolation using the paper TM, the Technician was required to approach this Fault Isolation as two separate Fault-Isolation problems, with the need to solve one problem before moving to the next.

With the IETM/PMA combination, the combined symptom set was addressed as a single fault (the tests used to solve the second fault [**e**.g., **5 (b)**] were a function of the tests used to solve the first fault [e.g., **5 (a)**]. The two fault combinations in this set involved defective wiring or connectors associated with:

5 (a) Trailing Edge Flap and **5 (b) Aileron Left.**

6 (a) Aileron Left Shutoff Valve and **6 (b) Leading Edge Flap Left.**

3.4.2 Fault Insertion

Inserting the two Electrical Faults [**1** and **2**] involved replacing good relays with ones that had failed in service. The next two faults [**3** and **4**] were CND situations and, whereas symptoms were provided, no fault was actually present. Each pair of Multiple Faults [**5 (a), 5 (b)** and **6 (a), 6 (b)**] was inserted non-destructively into the FCS of the F/A-18 using the Breakout Box.

The Breakout Box used to insert faults into the FCS was connected by cable to each of the two FCS computers (FCCA and FCCB). Each fault was associated with one of the Breakout-Box switches. Labels on switches identified the fault, e.g., in the label A-J1-2, the A meant FCC A; the J1 meant Computer Connector 1; and the 2 meant pin #2. The procedure for inserting faults using the Breakout Box was as follows:

a. Ensure that the test aircraft had been made safe for maintenance.

b. Apply ground-based electrical and hydraulic power to the aircraft.

c. Run preflight Initiated BIT (IBIT) to determine that the aircraft was fault-free.

d. Install fault-insertion tester into the system at the connectors of both flight-control computers (FCCA and FCCB). The Breakout Box was equipped with jumpers for opening the connection between the FCCs and the aircraft.

e. Run IBIT to determine that the FCS had remained fault-free.

f. Set desired fault on the Breakout Box.

g. Run IBIT to confirm intended fault state.

3.5 PREPARATION OF THE INTERACTIVE ELECTRONIC TECHNICAL MANUAL (IETM)

3.5.1 Work Package Source Data

Selected parts of the existing F/A-18 Work Package paper TMs were used as source data for the preparation of the IETM Technical Information. These were:

a. Fault Reporting Manual (FRM) - Consists of lists of BIT fault codes each of which refers to specific parts of other WPs for follow-up troubleshooting and repair.

b. 100 series manuals - contain theory of operation for the FCS.

c. 200 series manuals - contain troubleshooting instructions for major parts of the FCS; e.g., Wing Fold System.

d. 300 series manuals - contain Corrective-Maintenance instructions, e.g., remove and reinstall, align, rig.

e. 500 series manuals - contain a mixture of locator drawings and 9" x 14" sheets of schematics.

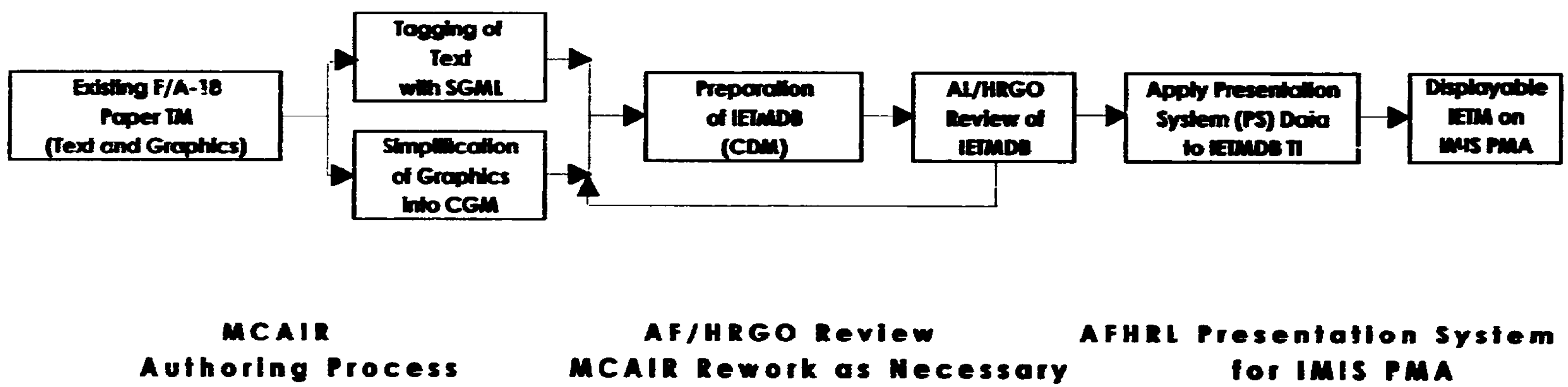
f. Line Maintenance Manual (LMM) series - doors and panels.

g. Plane Captain's manual.

3.5.2 Organizing the IETM

Material from the pertinent Work Packages (WPs) of the Flight Control System were formed into a database (IETMDB) organized according to the Content Data Model (CDM) concept. Elements of the CDM database were marked with Standard Generalized Markup Language (SGML) tags as required for data-exchange purposes. Before any part of this database could be viewed on the display of the Portable Maintenance Aid (PMA), the TI was extracted from the database and organized into a form that is viewable on the PMA. This ordering of the Technical Information in the IETMDB was accomplished by applying a set of algorithms (referred to as the IMIS Presentation System) hosted in the PMA. This overall sequence is summarized by Figure 2.

FIGURE 2



PROCESS USED TO CREATE IETM FOR F/A-18 TEST

3.5.3 IETM Reviews

Although, in general, IETM Quality Assurance procedures prescribed by MIL-Q-87270 [ref. 16], which had not as yet been issued, were not followed in preparation of the Test IETM materials, additional QA efforts performed during the preparation process included:

a. Human Factors (HF) Reviews of draft IETM to ensure that the information as shown on the IETM/PMA display did not deviate from accepted HF criteria, as reflected in the Human Computer Interface (HCI) [ref. 11], in MIL-M-87268 (ref. 2), and other relevant HF literature. In reviewing the draft IETM TI, HF personnel also took into account the following considerations:

   (1) Adequacy of amount of material. (Is the amount of text and graphic information usable by the Technician?).

   (2) Ease of following progressive sequences of illustrations (e.g., from work area to panel to relevant part).

   (3) Effectiveness of callouts (the number of callouts and the order of their appearance).

   (4) Legibility of relevant graphic items. (At normal reading distances, the items should be large enough to subtend a 12-minute arc at the viewer's eye).

   (5) Adequacy of the user/PMA interface, including the following considerations:

      (a) All required functions included?

      (b) Placement of priority keys.

      (c) Means of cursor control, e.g., joystick or cursor arrow keys.

      (d) Ease of operation, e.g., retrieval, navigation among different types of TI.

b. Performance of IETM Validation and Verification.

   (1) Validation.

   In preparing new Technical Information, either in paper form or as an IETM, Validation is a Contractor function which must be performed on the weapon system (aircraft or aircraft component) involved, using actual TI which is displayed on the same Display Device that is to be used by the maintenance technician. The purpose of Validation is to guarantee that all

TI content necessary to perform maintenance is present and accurate. For purposes of the F/A-18 test, however, Validation by MCAIR consisted of the following:

(a) Determined that the textual contents of the paper-TM and IETM Technical Information forms were in conformance.

(b) Determined that the locator graphics in paper form were equivalent to (presented the same information as) the locator graphics in IETM form.

(c) Determined that the text and graphics in the IETM were linked correctly.

(d) Determined that all IETM branching was present and that there were no dead ends.

(e) Determined that the IETM was viewable and usable on the IMIS PMA.

(2) Verification is a Government responsibility performed on the aircraft, using military technicians and IETM/PMA. The purpose of Verification is to assure the usability of the IETM/PMA in a realistic environment. A formal Verification was not conducted. Instead, during the Pretest which preceded the test, the test team, including operational personnel, reviewed the IETM/PMA to assess the usability of the IETM. Problems were corrected prior to the actual test.

3.6 DESCRIPTION OF SUBJECT TECHNICIANS

Sixteen Marine Corps Technicians participated in the test. All possessed specialties of either Electrician (Military Occupational Specialty 6337) or Communications/Navigation/ Radar (Military Occupational Specialty 6317). Eight of the Technicians were judged by their supervisors to be experienced in F/A-18 Flight Control System (FCS) maintenance; each of these Technicians had at least 24 months' experience of hands-on work on the FCS. The remaining eight Technicians were judged to be inexperienced, having 18 months or less on the FCS, with the average at 10.25 months. Fifteen of the sixteen Technicians were male; one was female.

Participation in the test was voluntary. All participants were briefed on the general nature of the test. All signed an Informed Consent Form.

3.7 DESCRIPTION OF THE TEST FACILITY

The Test Facility included two external hydraulic generators, the Breakout Box, a workstand for cockpit entry and exit, an intercom system, Workcenter spaces with TMs, briefing/debriefing areas and a portion of the hangar for the aircraft and its support equipment. Technicians were supplied with appropriate tool boxes and other required equipment. The same hangar space was used throughout the test.

3.7.1 The FCS and the Aircraft

The test vehicle was the Flight Control System (FCS) installed in a single F/A-18 aircraft (used throughout the test): Model C, Lot XIII. The aircraft was provided by VMFA-312, MCAS, Beaufort, SC. Parked inside a hangar with all (ground-based) power connected, the aircraft and its support equipment were roped off for safety purposes. All aircraft doors required for maintenance access remained open.

3.7.2 External Hydraulic Generators

Standard diesel-powered hydraulic generators were used to provide hydraulic power during execution of the test problems. VMFA-312 provided a qualified operator to run the generators. Refueling and monitoring the condition of the generators (especially by monitoring the temperature and by running occasional checks) was shared by VMFA's Safety Monitor and the generator Operator.

3.7.3 Breakout Box

The Breakout Box (see section 3.4.1) is described in ref. 13.

3.7.4 Workstand

A workstand of the type that rolls up to the side of the aircraft was used to facilitate personnel movement between the cockpit and the hangar floor, and to provide a perch for the team's technical observer while the Technician was performing cockpit checks.

3.7.5 Intercom

An intercom was used to provide communication among the Technician performing the maintenance task, the team's technical observer, and the data collector. The most frequent intercom communications were between the technical observer and the test Technician and between the technical observer and the data collector, e.g., the technical observer informed the data collector of the "handshake" (successful connection) between the 1553 multiplex bus and the PMA, or completion of a cockpit check, neither of which is observable from the hangar floor, the data collector's post.

3.7.6 Workcenter Spaces

Three separate work areas were provided in the VMFA-312 hangar and Administration Building. Space for the parked aircraft and its support equipment was provided directly outside of the Workcenter office and work-cage areas. One work-cage space (in the hangar building) was provided for test team equipment and personnel, and for Technician debriefing following each problem. Conference-room space was provided in the Administration Building for Orientation Briefings, form completion, and PMA/WP training.

3.8 DATA COLLECTION

3.8.1 Process

The following paragraphs identify the types of data collected and the means used for data collection.

a. PMA Training. The PMA training session consisted of oral descriptions, demonstrations of PMA capabilities, and hands-on Technician tryout and practice of these capabilities. Frequently, Technicians made favorable or critical comments regarding various features of the device or its displayed Technical Information during these sessions. The trainers documented these comments so that they could be included in the Debriefing Comment analysis.

b. Biographic Data Sheets. These forms asked for background on each Technician, e.g., service time, technical schools attended, time in squadron, and amount of hands-on experience. This information was used to establish the differences between personnel assigned to each experience

level; and if any Technician performed unusually well or poorly, to disclose whether or not anything in his background could be the cause of this extraordinary performance. An example of this form is provided in Appendix B.

c. Performance-Observation Forms. These forms (a sample is provided in Appendix C) listed four standard "Intervals" (see section 2.2.2) for each Fault-Isolation task. (The CND problem type did not include the Parts-Ordering Interval.) The data collectors, in close communication with the technical observer, entered start times for each Interval (the stop time for an Interval was the start time for the following Interval). The form provided space for entering notes on observed errors. Errors tended to be of three types: (1) Procedural (took the wrong branch after a test outcome), (2) False Removals or (3) Failure to Isolate the Fault. The data collectors noted any other significant behavior (good and bad) for discussion with the Technician during Debriefing. Technicians' performance times and procedural-error data were analyzed statistically; content analyses were performed on the Debriefing comments.

Time and error data of the type discussed above were collected for each of the following sequential test Intervals (see section 3.8.4):

(1) Preparation.

(2) Fault Isolation.

(3) Parts Ordering.

(4) Maintenance Close-out.

d. Debriefing. Notes on any significant behavior which the data collectors observed during a Technician's performance were entered on the Performance Observation Form. Later during debriefing, the data collectors used these notes to initiate Debriefing discussions, which were held after each problem performance. Two sample videos were made and retained to illustrate the nature of these interviews: one for an experienced Technician and one for an inexperienced Technician.

e. User-Evaluation Questionnaire. After finishing the six Fault-Isolation tasks, each Technician was asked to complete a User-Evaluation Questionnaire (a form is provided in Appendix D). Thus, each Technician's bases for responding to the Questionnaire items consisted of three maintenance tasks guided by the IETM/PMA combination and three guided by paper TMs. (See Table 3).

Each use of the IETM/PMA in a particular Fault-Isolation effort was paired with a paper-TM use in support of the other test of that type. A Technician responded to items of the Questionnaire by selecting one of five scale values indicating the Technician's opinions regarding the pertinent IETM or PMA feature. The scale values ranged from Unsatisfactory to Outstanding. The Questionnaire items covered the IETM/PMA areas of:

(1) PMA physical dimensions.

(2) Keyboard layout.

(3) Display characteristics (brightness, contrast).

(4) Comprehensibility of IETM formats.

(5) Cursor, menu, and information-access features.

(6) Text and graphics adequacy.

(7) Automatic form-completion procedures.

(8) Other comments.

f. Structured Interview. The structured interview posed 16 questions to elicit the Technicians' opinions of the PMA. A major purpose of the interviewer was to use these questions as the basis for expanding the discussion into other areas. Two of the sixteen questions dealt with "most liked - least liked" IETM/PMA features. A copy of the Structured Interview Guide is provided in Appendix E.

g. Team Personnel Observation. The final source of data was the interaction of the test-team members with, and observation of, the participating Technicians. Each team member documented his observations on the design and use of the IETM/PMA combination. Comments included such opinions and such factors as consistency with the way the squadron does maintenance, ways that IETM/PMA usage might be expanded, and the features of the device itself. Comments which were not already covered by other sources became a part of the Debriefing Comments which appear in section 4.2 of this report.

3.8.2 Test-Team Personnel

The test-team personnel who administered the F/A-18 IETM/PMA field test were as follows:

a. Test Director (One per shift). Two scientists, one from AL/HRGO and one from NCC&OSC, were responsible for directing the overall effort. Specific responsibilities of the Test Directors included:

   (1) Acting as the Government's agents in matters involving planning, scheduling and conduct of the test.

   (2) Providing principal liaison among NAVAIR, VMFA-312, CDNSWC and AL/HRGO.

   (3) Ensuring smooth operation of the pilot study and the test, as well as proper evaluation of their results.

b. Navy Liaison (One, from CDNSWC). This test was co-sponsored by the Navy (NAVAIR 411) and the US Air Force (AL/HRGO). Liaison was provided between the test team and the sponsoring organization throughout the development of the IETM/PMA combination and the Test Plan (ref. 15); and the conduct of the Pretest (Pilot Test) and the Test including the data analysis and report preparation. Specific duties included:

   (1) Progress reporting and resolution of problems during IETM/PMA development, Test Plan development, test conduct, and report preparation.

   (2) Site selection for the IETM/PMA tryouts, performance of the Pretest and Test, especially through interaction with VMFA-312 and COMNAVAIRLANT.

c. Safety Monitor (One per shift). Safety monitors, provided by VMFA-312, were senior Technicians qualified in all aspects of the F/A-18 FCS. Primary responsibilities were to monitor Technicians' performance in order to:

   (1) Ensure safety, especially for the Technicians serving as participants.

   (2) Resolve conflicts concerning the use of VMFA-312 resources, e.g., aircraft, test equipment, spaces, personnel, and Technical Information.

   (3) Coördinate the scheduling and support of Technicians serving as test participants.

(4) Ensure that no damage was done to any of the equipment involved (the aircraft FCS, test equipment, and support equipment).

(5) Assist test participants in the performance of multi-person tasks (in accordance with an established test-performance protocol).

d. Technical Observers (One per shift from AL/HRGO Contractors MCAIR and SEI). These Contractor personnel observed the participating Technicians' step-by-step actions throughout performance of the test tasks. These personnel were expert on the F/A-18 FCS, its maintenance, the paper-based TMs, and the IETM/PMA combination. Their responsibilities included:

(1) Safeguarding personnel and equipment.

(2) Communicating performance times, errors, and task status to the Data Collectors.

(3) Evaluating Procedural Errors and False Removals; and judging success or failure in Fault Isolation.

e. Trainers. (Three, scheduled as necessary to meet training needs. Training personnel consisted of Air Force officers on the staff of AL/HRGO and a representative of the University of Dayton Crew Systems Ergonomics Information Analysis Center). These personnel developed and administered the IETM/PMA and paper-TM training programs, both initial and refresher sessions. Responsibilities included:

(1) Administering the Overview Briefing, the Informed Consent Form and the Biographical Data Forms.

(2) Interacting with the Test Directors to establish upcoming run schedules and associated training needs.

(3) Administering initial training, criterion testing, and remedial training as necessary; and providing refresher training for both the IETM/PMA and the paper TMs.

f. Data Collectors (Two per shift, consisting of civilian and military staff members of AL/HRGO and a representative of Scientific Management Associates). Data collectors recorded Technicians' performance times and error data, and solicited opinion data during debriefing sessions. Data collector efforts overlapped; that is, while Collector Number 1 monitored the performance of one

Technician, Collector Number 2 was debriefing the previous Technician. Specific responsibilities of this position included:

(1) Assuring a smooth flow of test participants.

(2) Monitoring the performance of the test participants and recording observations on the Performance Observation Forms.

(3) Participating in the resolution of problems, misunderstandings, or procedural issues with the test Technicians and other test-team members.

(4) Administering the User Questionnaire and Structured Interview following a test participant's performance.

g. Technical Support (Three personnel scheduled as necessary throughout the test). These personnel were PMA software and hardware experts. The positions were filled by personnel under contract to AL/HRGO. Specific duties included:

(1) Monitoring the status of the PMAs, drives, and batteries including the use and recharge cycles.

(2) Monitoring the operation of the PMA hardware and software; resolving any problems encountered with the device during the test.

(3) Providing video recordings during the structured interviews.

3.8.3 Materials and Recording Forms

All materials and forms used in the test are listed below. Their use has been described in section 3.8.1. Samples of four of these materials appear as Appendixes B through E.

1. Orientation Briefing
2. Informed Consent Form
3. Biographic Data Sheet (B)
4. Training Syllabus
   IETM/PMA
   Paper TMs
5. Performance Observation Form (C)
6. User Evaluation Questionnaire (D)
7. Structured Interview Form (E)

3.8.4 Performance Measures and Quantitative Data

Data cited in the following paragraphs were collected throughout the test. All maintenance actions were divided into seven sequential Intervals to accommodate collection of performance times.

3.8.4.1 Definitions of Test Intervals

a. **Preparation Interval.** Started when subject (while in the Work Center) was handed the VIDS/MAF describing the symptom; it ended when he arrived at the aircraft with his collected resources.

b. **Fault-Isolation Interval.** Started when the Technician arrived at the aircraft; it ended either when he announced the correct cause of the fault symptom (i.e., identified the faulty WRA) or when the pre-established maximum time limit was reached.

c. **Wire-Repair or WRA-Removal Interval.** **WRA Removal** started when the Technician announced the correct cause of the discrepancy; it ended when the removal procedure had been found and very briefly reviewed with the Technical Observer. (The Technical Observer told the Technician to assume that the repair had been done).

   Wire Repair started when the Technician announced the cause of the discrepancy; it ended when the wire-repair procedure had been found and very briefly reviewed with the Technical Observer. (The Technical Observer told the Technician to assume that the repair had been done).

d. **Parts-Ordering Interval.** Started when the Repair/Removal review was complete; it ended when the appropriate portions of the VIDS/MAF were complete.

e. **Reinstallation Intervals** started when the Parts-Ordering portion of the VIDS/MAF was complete; it ended when the reinstallation procedure had been located and reviewed very briefly with the Technical Observer. (As with Interval **c.**, the procedure was assumed.)

f. **System Health-Check Interval.** This Interval was carried out to determine the fault status of the aircraft; i.e., fault-free if the Fault-Isolation procedure was correct. It was usually a shortcut check accomplished by the Technical Observer. It started when the review of the Reinstallation or Repair was complete; it ended when the results of the Check were announced by the Technical Observer.

g. **Maintenance Close-Out Interval** started when the positive (fault-free) Health-Check results were announced; it ended when the Technician had completed all entries in the VIDS/MAF.

3.8.4.2 Data Collected

For completeness, performance-time data were collected for all seven Test Intervals, but due to the simulated nature of parts of the Wire-Repair or WRA-Removal Interval, the Reinstallation Interval, and System-Health Check Interval (necessary to assure continuity of the entire maintenance process), only the data from the Preparation, Fault-Isolation, Parts-Ordering, and Maintenance Close-out Intervals are reported and analyzed in this report. Specifically, the following data are presented and analyzed:

a. **Preparation-Time Interval** - The elapsed time from the initial receipt of the VIDS/MAF to the time the Technician arrived at the aircraft with all tools and resources.

b. **Fault-Isolation Interval** - The time required to perform diagnostic and testing actions, e.g., time from arrival at the aircraft to the time when faulty WRA was identified (or the time limit was reached without selection).

c. **Parts-Ordering Interval** - Time required to fill out the parts-requisition form. This Interval started immediately upon identifying the faulty component and ended when the parts requisition form had been completed. (Data of this type were collected only for the Relay Tests.)

d. **Maintenance Close-Out Interval** - The elapsed time to obtain and enter the data required for the VIDS/MAF.

e. **Overall Time to Maintenance Completion** - The total time required to complete the processing, consisting of all four actions (cited in **a.** through **d.**, above).

f. **Failure to Identify the Fault (FI)** - Technician's failure to identify the failed component.

g. **False Removal (FR)** - An incident in which the Technician recommended the removal of a non-faulty component erroneously believing it to be the cause of the fault symptom.

h. **Procedural Errors** - The number of procedural errors, such as misinterpretation of the TI or improper use of the test equipment.

i. **Total Errors** - The total number of Failures to Identify Fault, False Removals, and Procedural Errors.

3.8.5 Descriptive Measures

Analyses were performed on data collected from the Biographic Data Sheet, User Evaluation Questionnaire, and Structured Interview.

The biographic data determined the extent to which the Technician participants assigned to the two levels of experience differed on such variables as:

a. Current enlisted pay grade.

b. Years and months of aircraft maintenance experience in general.

c. Years and months of aircraft maintenance experience on the FCS.

d. Number of enlisted occupational specialties held.

e. Previous computer usage.

These analyses indicated that the two groups were significantly different in levels of maintenance experience.

Responses to the first three sections of the User Evaluation Questionnaire were analyzed both numerically and qualitatively.

In the numerical analysis, mean ratings were computed for items related to:

a. Physical features of the IMIS PMA.

b. Its operation and software features.

c. The relative efficiency and effectiveness of the IETM compared to paper manuals. Further, the open-ended comments provided in the final section of the questionnaire were examined as possible explanations for uniformly low ratings, and to identify suggestions the test participants had for improving the PMA used in the test.

Content analyses of test participants' responses to the structured-interview items concentrated on identifying and categorizing those aspects of the IETM/PMA operations and usage that may require corrective action or further RDT&E. In addition, analysts noted those features of the IETM/PMA that were particularly liked by the test participants and supplemented them with impressions of the test team members where appropriate.

4.0 RESULTS

This Section describes the findings of the field test of the F/A-18 IETM/PMA combination. The data include:

a. The quality of Technician performance while using the IETM/PMA as compared with performance using conventional paper TMs.

b. Technicians' comments gathered during the various debriefings and interviews.

A discussion (section 5) follows the presentation of each of these sets of findings.

4.1 PERFORMANCE RESULTS

This section presents the performance-effectiveness findings including:

a. Performance times (Preparation, Fault-Isolation, Parts-Ordering, Maintenance Close-Out Intervals; and Overall Total).

b. Errors (Procedural Errors, Failures to Identify Fault, and False Removals).

4.1.1 Performance Times

4.1.1.1 Performance Times for the Preparation Interval

The Preparation Interval started when the data collector handed the VIDS/MAF in either paper or IETM form (i.e., displayed on a PMA) to the Technician; the Interval ended when the Technician (having assembled all tools, TI, and materials needed for the test at hand) arrived at the aircraft. Table 4 shows the mean Preparation times by experience level, by fault type, and by presentation medium. Figures 3 and 4 show performance times for this Interval, with comparisons based, respectively, on the two experience levels of the Technicians, and on the two types of medium. For tests in which IETMs were used, the Technical Information required had already been fully loaded into the PMA (by the Work-Center staff, prior to, or as part of, the assignment of the Technician to the Fault-Isolation task), but for tests

TABLE 4

TIME (MINUTES) REQUIRED FOR PREPARATION INTERVAL (ALL TESTS)

TECHNICIANS	RELAY			CAN NOT DUPLICATE (CND)			MULTIPLE		
EXPERIENCED	IETM	Paper	RATIO	IETM	Paper	RATIO	IETM	Paper	RATIO
S1	2	4	0.500	14	–	–	2	4	0.500
S2	3	4	0.750	2	5	0.400	2	5	0.400
S3	1	1	1.000	3	–	–	2	13	0.154
S4	3	2	1.500	3	4	0.750	3	2	1.500
S5	3	4	0.750	1	5	0.200	1	6	0.167
S6	2	6	0.333	3	3	1.000	2	6	0.333
S7	1	6	0.167	2	5	0.400	5	13	0.385
S12	2.5	4	0.625	3	3.5	0.857	2	5	0.400
AVERAGE:	2.19	3.88	0.703	3.88	4.25	0.601	2.38	6.75	0.480
INEXPERIENCED	IETM	Paper	RATIO	IETM	Paper	RATIO	IETM	Paper	RATIO
S9	2	6	0.333	3	–	–	4	3	1.333
S10	10	10	1.000	3	VOID	–	2	12	0.167
S11	6	3	2.000	2	4	0.500	2	8	0.250
S13	6	3	2.000	1	2	0.500	4	10	0.400
S14	1	12	0.083	2	7	0.286	2	4	0.500
S16	1	8	0.125	1	–	–	1	4.5	0.222
S17	2	6	0.333	3	5	0.600	2	7	0.286
S18	2	7	0.286	2	4	0.500	1	3	0.333
AVERAGE:	3.75	7.00	0.770	2.13	4.40	0.477	2.25	6.44	0.436

NOTE: TABLE 4 presents all data obtained for the Preparation Interval (see paragraph 4.1.1.1) for each of the 96 tests performed. (See TABLE 3.)

FIGURE 3
COMPARISON OF PERFORMANCE OF INEXPERIENCED TECHNICIANS
WITH THAT OF EXPERIENCED TECHNICIANS.
(AVERAGE PERFORMANCE TIMES IN MINUTES REQUIRED; ALL TESTS)

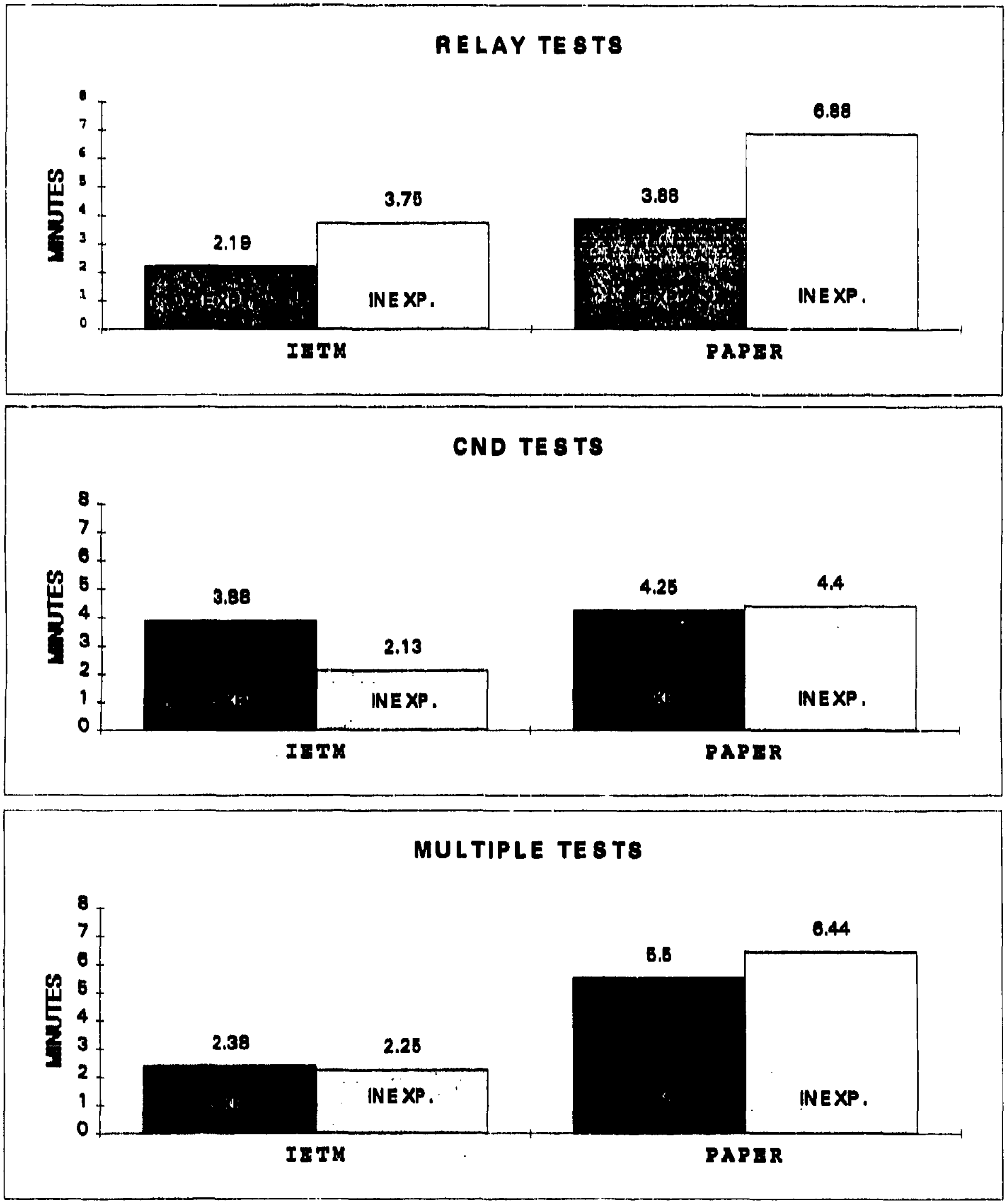
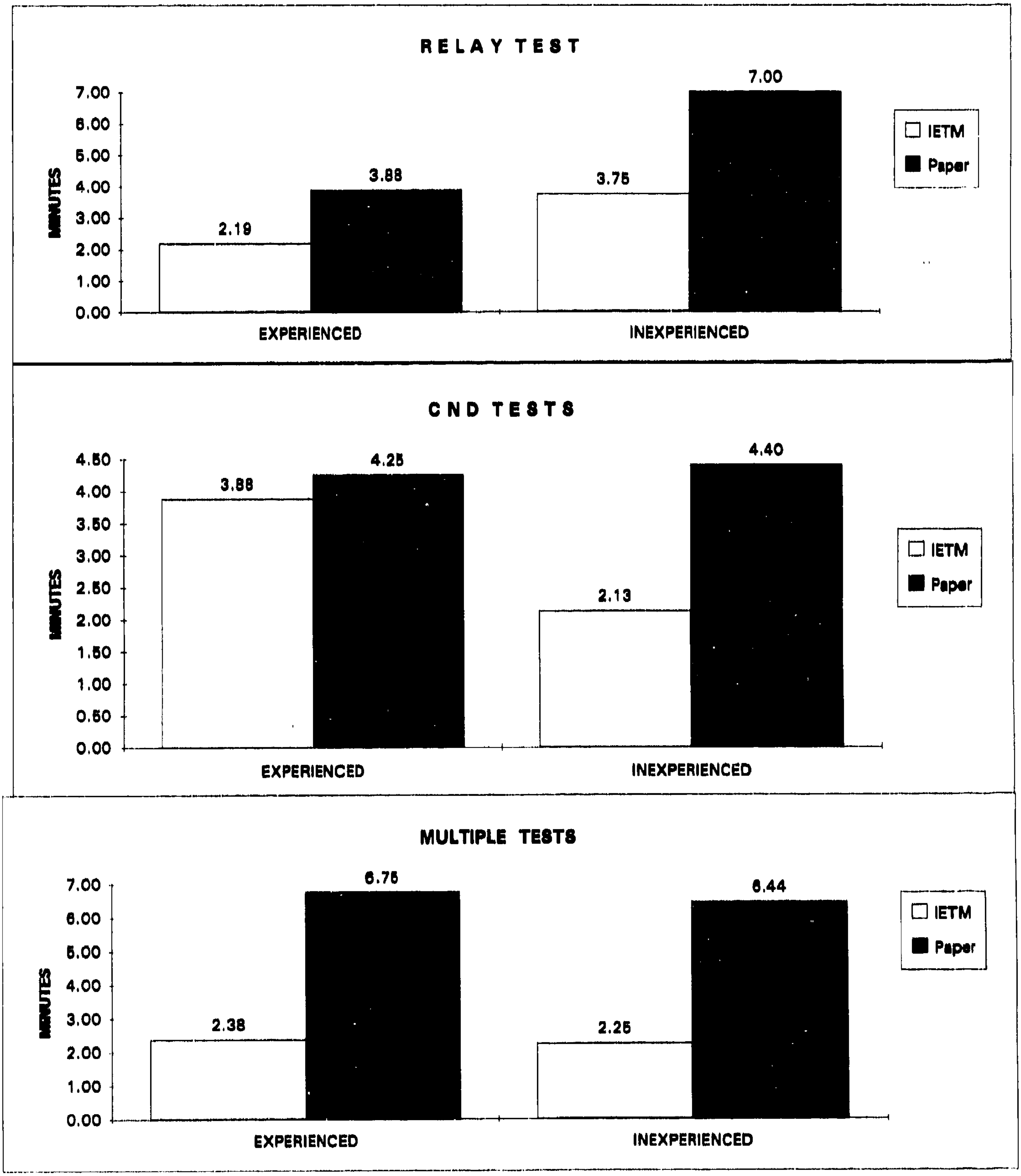


FIGURE 4
Comparison of Performance of Technicians Using IETMs with that of Technicians Using Paper TMs, for Preparation Interval
(Average Times in Minutes Required; All Tests)



using paper TMs, the time required to locate the appropriate paper-based TI was included in the performance-time record. Thus, the Preparation-Interval measurement was designed to assess Technicians' time required to assemble paper-based TI for an assigned task: [Time(paper) - Time(IETM)] = Time to assemble paper TI, which is the primary time-consuming effort in this short Interval.

Table 5 shows the average ratios of Technician performance times for the Preparation Interval with IETM use to those with paper-TM use. Note that in every case this ratio is less than 1; i.e., for this Interval, use of IETMs decreased performance times for all combinations, by the factors shown.

4.1.1.2 Performance Times for Fault Isolation

The Fault-Isolation Interval started when the Technician arrived at the aircraft and ended when the Technician announced his finding: e.g., "This is a CND". Table 6 presents mean performance times for this Interval by experience level, by fault type, and by type of TM used. Figures 5 and 6 show performance times for this Interval with comparisons based, respectively, on the two experience levels of the Technicians and on the two types of medium. Table 7 shows the ratios of performance times for the Fault-Isolation Interval with IETM use to those with paper-TM use.

4.1.1.3 Performance Times for Parts Ordering

The Parts-Ordering Interval commenced when the Wire-Repair or WRA Removal Interval had been completed (see section 3.8.4) and ended with the completion of the Parts-Ordering form. (Parts Ordering was not performed for the CND tests). Table 8 presents the mean performance times for the Parts-Ordering Interval by fault, by experience level, and by medium. Figures 7 and 8 show performance times for this Interval with comparisons based, respectively, on the two experience levels of the Technicians and on the two types of medium. Table 9 shows the ratios of performance times for the Parts-Ordering Interval with IETM use to those with paper-TM use.

TABLE 5
Effect of Using IETMs Instead of Paper TMs
in Preparation Interval (All Tests)

AVERAGES OF INDIVIDUAL RATIOS OF

$$\frac{\text{PERFORMANCE TIME (IETM)}}{\text{PERFORMANCE TIME (PAPER)}}$$

for each technician

	RELAY TESTS
Experienced Technicians	0.703
Inexperienced Technicians	0.770

	CND TESTS
Experienced Technicians	0.601
Inexperienced Technicians	0.477

	MULTIPLE TESTS
Experienced Technicians	0.460
Inexperienced Technicians	0.436

TABLE 6

TIME (MINUTES) REQUIRED FOR PERFORMANCE OF FAULT ISOLATION (FAULT-ISOLATION INTERVAL; ALL TESTS)

TECHNICIANS	RELAY			CAN NOT DUPLICATE (CND)			MULTIPLE		
EXPERIENCED	IETM	Paper	RATIO	IETM	Paper	RATIO	IETM	Paper	RATIO
S1	23	30	0.767	55	–	–	51	63.5	0.803
S2	49	35	1.400	36	38	0.947	55	106	0.519
S3	49.5	52	0.952	51.5	–	–	102	62	1.645
S4	32	39	0.821	48	60	0.800	45	67	0.672
S5	32	42	0.762	26	52	0.500	86	63	1.365
S6	61	46	1.326	26	68	0.382	64	66	0.970
S7	48	38	1.263	22	41	0.537	71	87	0.816
S12	27.5	33	0.833	43	–	–	44	96	0.458
AVERAGE:	40.25	39.38	1.015	38.44	51.80	0.633	64.75	76.31	0.906
INEXPERIENCED	IETM	Paper	RATIO	IETM	Paper	RATIO	IETM	Paper	RATIO
S9	59	61	0.967	55	–	–	55	113	0.487
S10	52	69	0.754	56	VOID	–	71	155	0.458
S11	43	45	0.956	52	31	1.677	65	78	0.833
S13	46	36	1.278	40	46	0.870	56	76	0.737
S14	46	35	1.314	26	41.5	0.627	59	59	1.000
S16	34	46	0.739	46	–	–	47	102.5	0.459
S17	31	61	0.508	39	62	0.629	39	77	0.506
S18	46	53	0.868	25	42	0.595	90	64	1.406
AVERAGE:	44.63	50.75	0.923	42.38	44.50	0.880	60.25	90.56	0.736

FIGURE 5

Comparison of Performance of Experienced Technicians with that of Inexperienced Technicians, for Fault-Isolation Interval (Average Times in Minutes; All Tests)

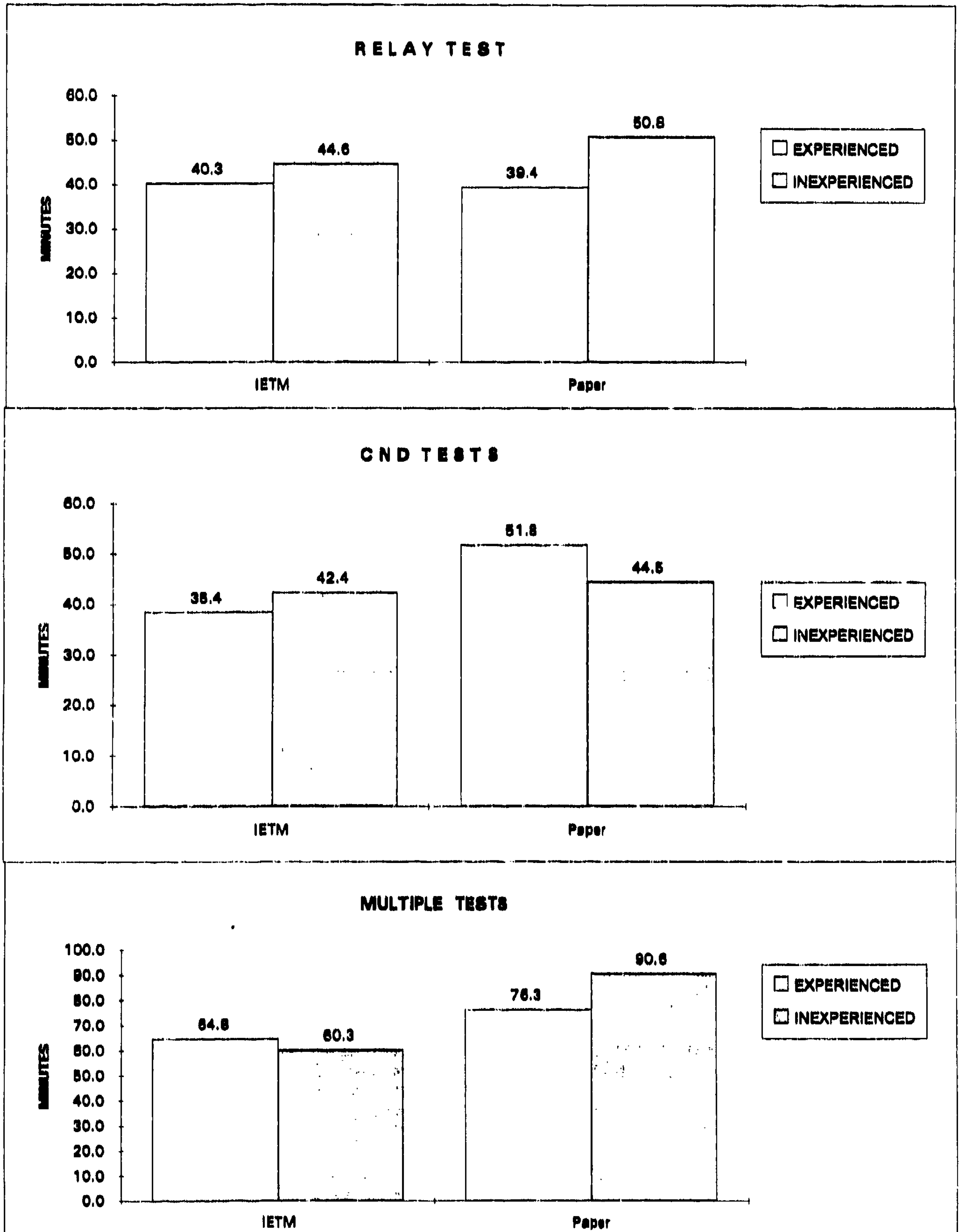


FIGURE 6
Comparison of Performance of Technicians Using IETMs with that of Technicians Using Paper TMs, for Fault-Isolation Interval
(Average Times in Minutes; All Tests)

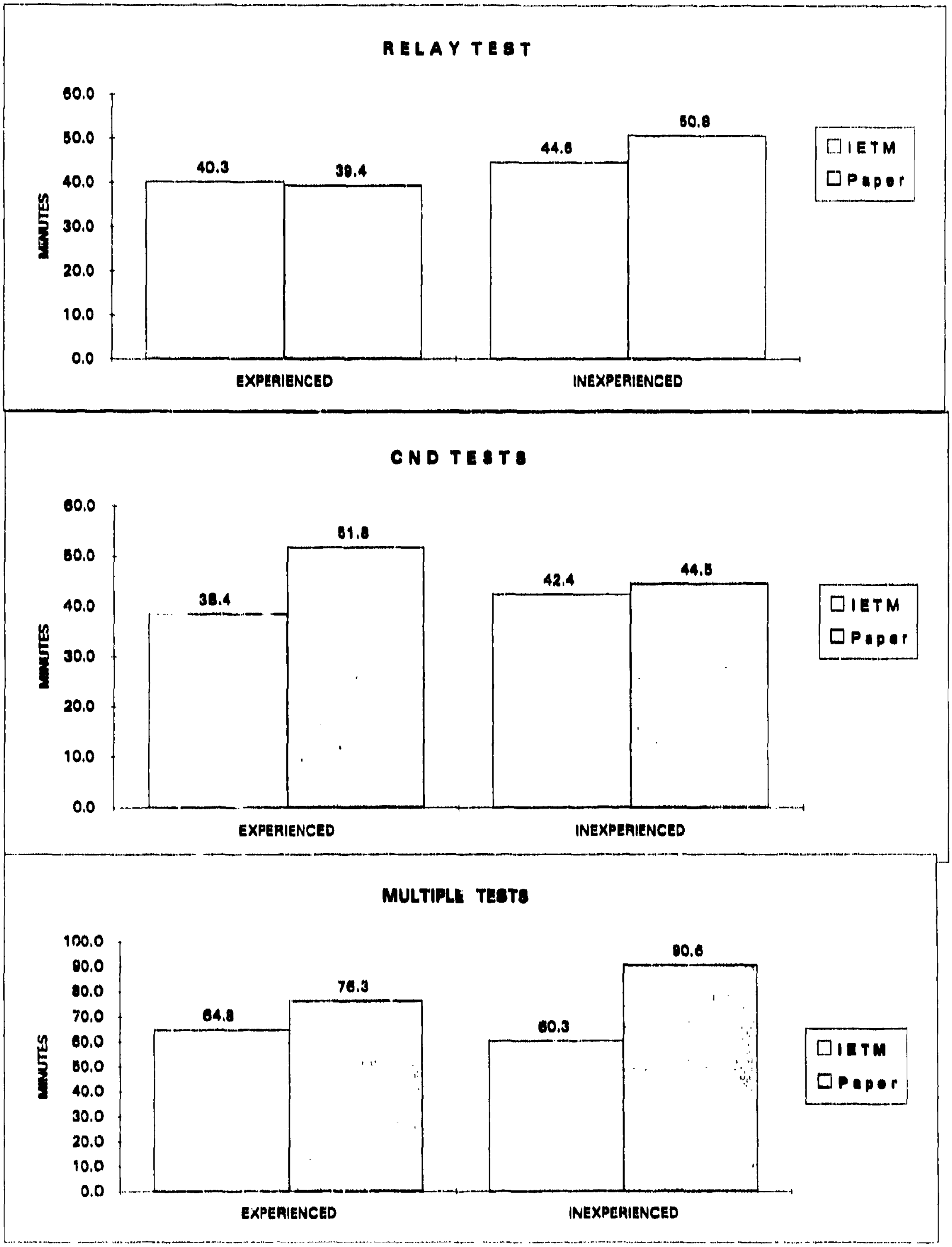


TABLE 7
Effect of Using IETMs Instead of Paper TMs in Fault-Isolation Interval (All Tests)

AVERAGES OF INDIVIDUAL RATIOS OF

$$\frac{\text{PERFORMANCE TIME (IETM)}}{\text{PERFORMANCE TIME (PAPER)}}$$

for each technician =

$$\frac{1}{n}\sum_{S_1}^{S_n}\left|\frac{t(\text{IETM})_i}{t(\text{PAPER})_i}\right|$$

	RELAY TESTS
Experienced Technicians	1.015
Inexperienced Technicians	0.923

	CND TESTS
Experienced Technicians	0.633
Inexperienced Technicians	0.880

	MULTIPLE TESTS
Experienced Technicians	0.906
Inexperienced Technicians	0.736

Note that the above ratio is not, in general, equal to:

$$\frac{\frac{1}{n}\sum_{S_1}^{S_n} t(\text{IETM})_i}{\frac{1}{n}\sum_{S_1}^{S_n} t(\text{PAPER})_i}$$

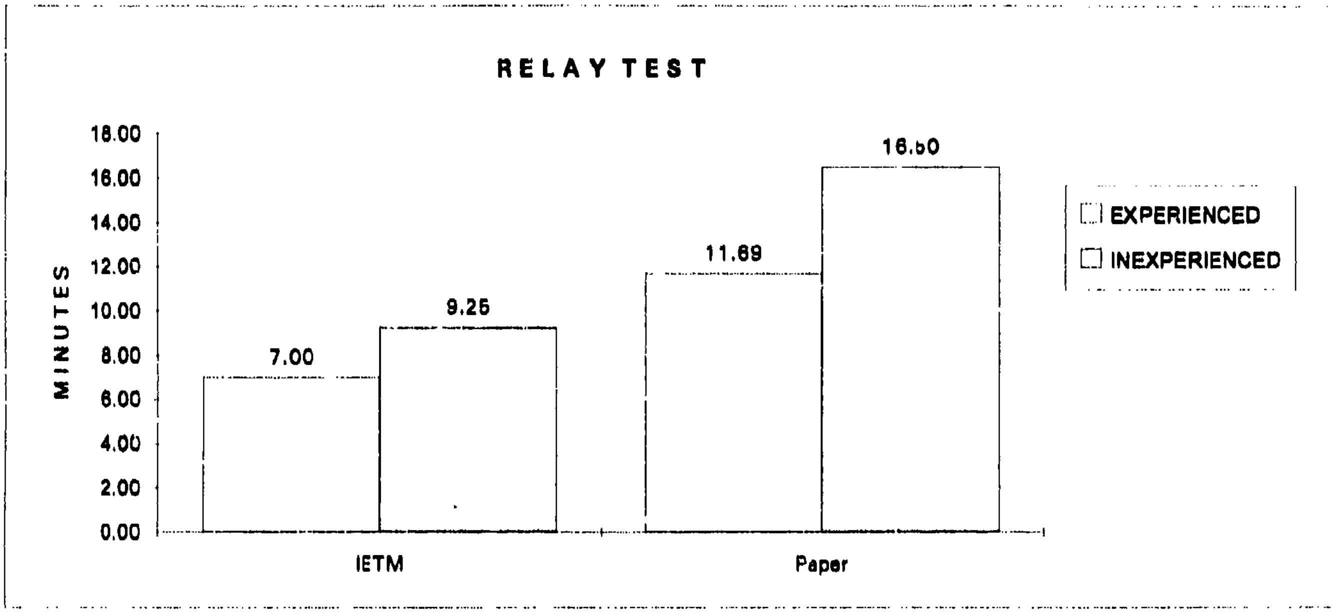
TABLE 8

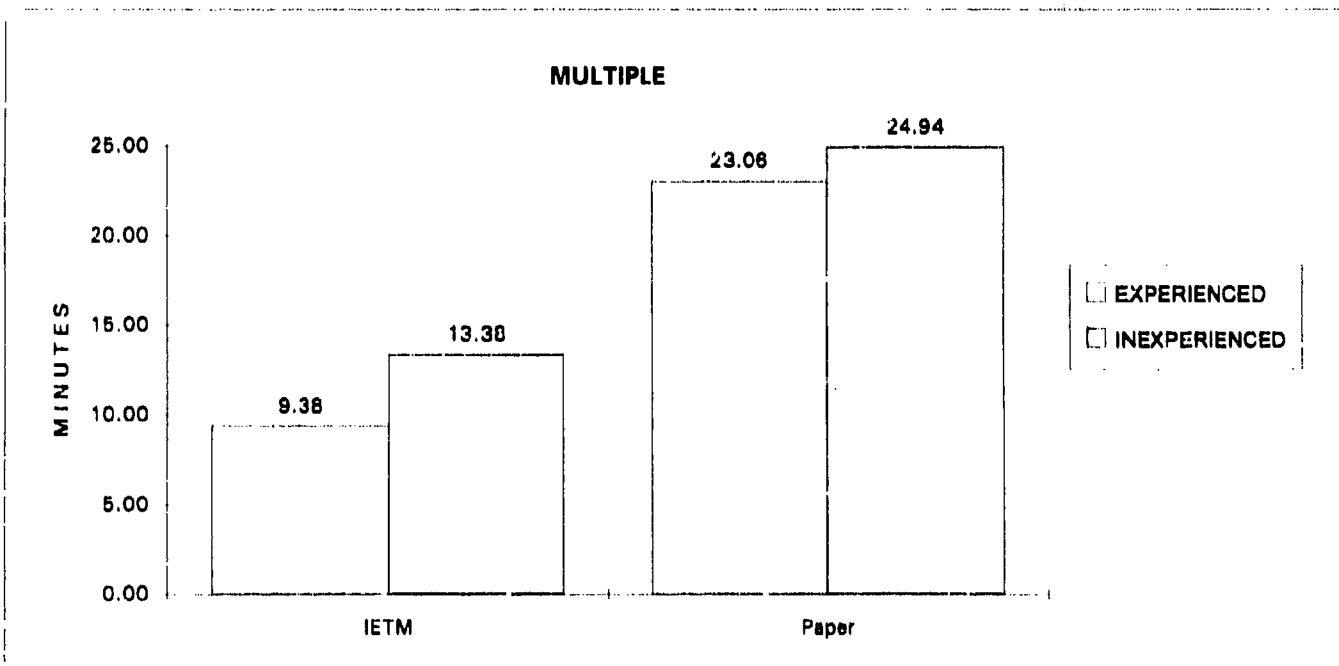
TIMES (MINUTES) REQUIRED FOR PERFORMANCE OF PARTS ORDERING
(PARTS-ORDERING INTERVAL; NOT APPLICABLE TO CND TESTS)

TECHNICIANS	RELAY			MULTIPLE		
EXPERIENCED	IETM	Paper	Ratio	IETM	Paper	Ratio
S1	5	23	0.217	12	21	0.571
S2	11	24	0.458	9	9	1.000
S3	12	13	0.923	7	17	0.412
S4	7	6	1.167	12	33	0.364
S5	6	3	2.000	8	22	0.364
S6	6	9	0.667	9	27	0.333
S7	4	7	0.571	10	26	0.385
S12	5	8.5	0.588	8	29.5	0.271
AVERAGE:	7.00	11.69	0.824	9.38	23.06	0.462
INEXPERIENCED	IETM	Paper	Ratio	IETM	Paper	Ratio
S9	5	34	0.147	16	26	0.615
S10	7	16	0.438	14	29	0.483
S11	10	5	2.000	13	20	0.650
S13	13	12	1.083	10	14	0.714
S14	6	11	0.545	18	17	1.059
S16	8	12	0.667	10	22.5	0.444
S17	10	22	0.455	10	36	0.278
S18	15	20	0.750	16	35	0.457
AVERAGE:	9.25	16.50	0.761	13.38	24.94	0.588

FIGURE 7

Comparison of Performance of Experienced Technicians with that of Inexperienced Technicians, for Parts-Ordering Interval (Average Times in Minutes Required; Relay Tests and Multiple Tests)





F I G U R E 8

Comparison of Performance of Technicians Using IETMs with that of Technicians Using Paper TMs, for Parts-Ordering Interval (Average Times in Minutes Required; Relay Tests and Multiple Tests)

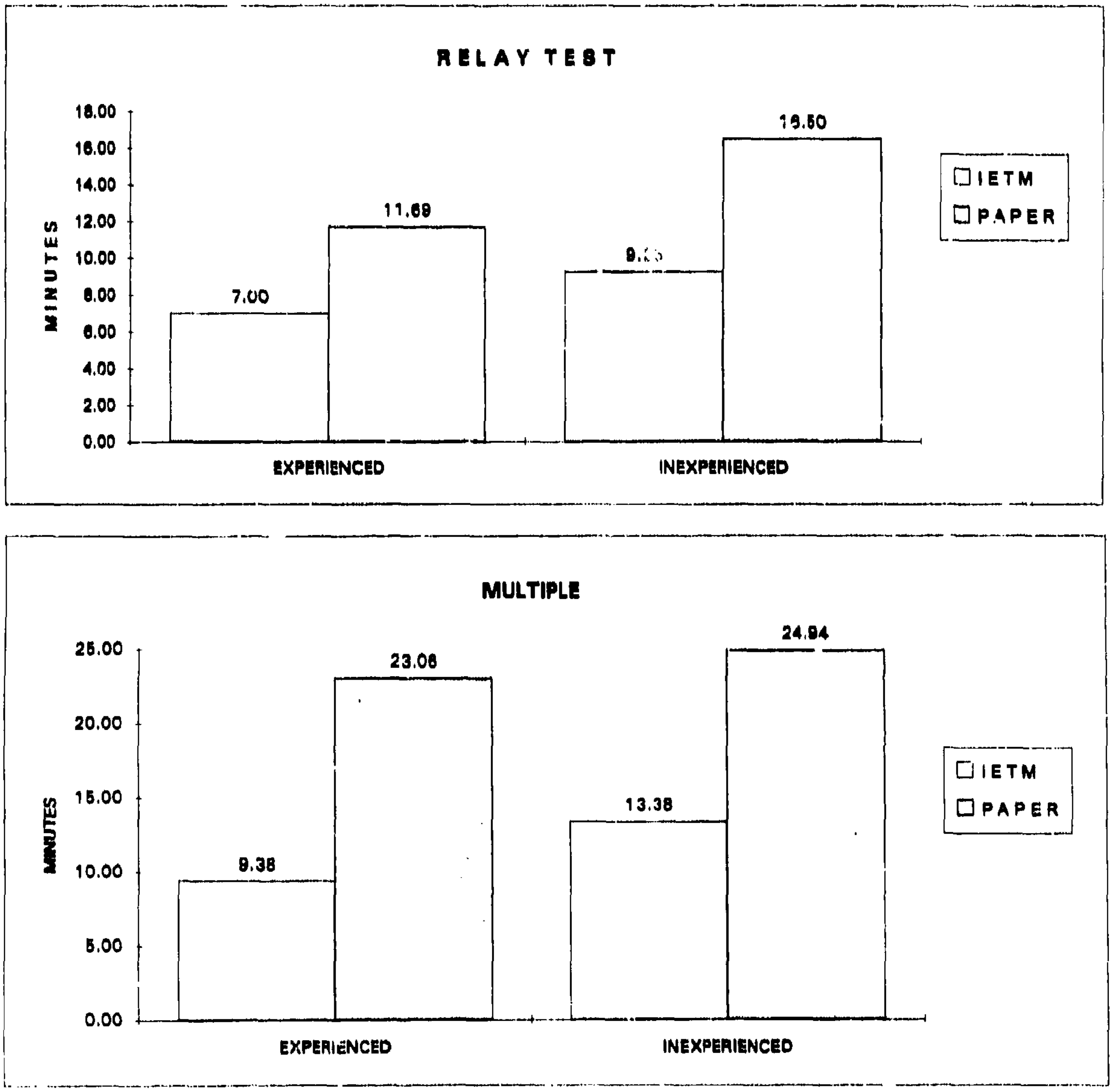


TABLE 9
Effect of Using IETMs Instead of Paper TMs in Parts-Ordering Interval

AVERAGES OF INDIVIDUAL RATIOS OF

$$\frac{\text{PERFORMANCE TIME (IETM)}}{\text{PERFORMANCE TIME (PAPER)}}$$

for each technician

	RELAY TESTS
Experienced Technicians	0.824
Inexperienced Technicians	0.761

	MULTIPLE TESTS
Experienced Technicians	0.462
Inexperienced Technicians	0.588

4.1.1.4 Performance Times for Maintenance Close-Out Interval

The Maintenance Close-Out Interval started when the Technician had completed a System-Health check (or with the declaration of a CND status for CND faults) and ended when the Close-Out portion of the VIDS/MAF was complete (see section 3.8.4). Table 10 presents the mean performance times for this Interval by fault type, by experience level and by medium. Figures 9 and 10 show performance times for this Interval with comparisons based, respectively, on the two experience levels of the Technicians and on the two types of medium. Table 11 shows the ratios of performance times for the Maintenance Close-Out Interval with IETM use to those with paper-TM use.

4.1.1.5 Overall Performance Times

The Fault-Isolations that the Technicians were asked to perform included seven task Intervals; the Overall (total) Performance Time is the sum (for each Technician) of the times for four of these Intervals (Preparation, Fault-Isolation, Parts-Ordering, and Maintenance Close-Out). See sections 3.8.4.1 and 3.8.4.2. Tables 12-17 present the Overall performance times for each of the four Intervals analyzed and the Overall times for the total test sequence: by fault type, by experience level, and by medium. Figures 11 and 12 compare Overall performance times, with comparisons based, respectively, on the two experience levels of the Technicians and on the two types of medium. Table 18 summarizes Overall test performance times with IETM support and with paper-TM support for each test type and provides the performance-time ratios for each Technician. Table 19 summarizes the ratios of Overall performance time with IETM support to that with paper-TM support.

4.1.2 Performance Errors

Performance errors made by the Technicians are of three types:

a. Procedural Errors.

b. False Removals (removal of good components thought to be faulty).

c. Failures to Identify the Fault, or to identify the problem as a CND (Failure to Fault Isolate)

Numbers of each type of error are presented in the following sections, and summarized in Table 20.

TABLE 10

TIMES (MINUTES) REQUIRED FOR PERFORMANCE OF MAINTENANCE CLOSE-OUT INTERVAL (ALL TESTS)

TECHNICIANS	RELAY			CAN NOT DUPLICATE (CND)			MULTIPLE		
EXPERIENCED	IETM	Paper	RATIO	IETM	Paper	RATIO	IETM	Paper	RATIO
S1	1	3	0.333	2.5	–	–	1	6	0.167
S2	1	1	1.000	5	5	1.000	2	8	0.250
S3	1	1	1.000	5	–	–	1	16	0.063
S4	2	4	0.500	4	3	1.333	1	8	0.125
S5	4	7	0.571	1	5	0.200	1	6	0.167
S6	2	5	0.400	1	3	0.333	1	4	0.250
S7	1	5	0.200	3	4	0.750	2	14	0.143
S12	3.5	7	0.500	1	4.5	0.222	3	7	0.429
AVERAGE:	**1.94**	**4.13**	**0.563**	**2.81**	**4.08**	**0.640**	**1.50**	**8.63**	**0.199**
INEXPERIENCED	IETM	Paper	RATIO	IETM	Paper	RATIO	IETM	Paper	RATIO
S9	6	8	0.750	7	–	–	4	8	0.500
S10	1	1	1.000	3	VOID	–	1	8	0.125
S11	3	3	1.000	2	2	1.000	3	10	0.300
S13	4	3	1.333	5	2	2.500	3	8	0.375
S14	3.5	5	0.700	1	4.5	0.222	0.5	8	0.063
S16	1.5	6	0.250	1	–	–	4	8.5	0.471
S17	3	5	0.600	3	6	0.500	1	9	0.111
S18	3	6	0.500	5	6	0.833	2	9	0.222
AVERAGE:	**3.13**	**4.63**	**0.839**	**3.38**	**4.10**	**1.011**	**2.31**	**8.56**	**0.271**

FIGURE 9

Comparison of Performance of Experienced Technicians with that of Inexperienced Technicians, for Maintenance Close-Out Interval (Average Times in Minutes; All Tests)

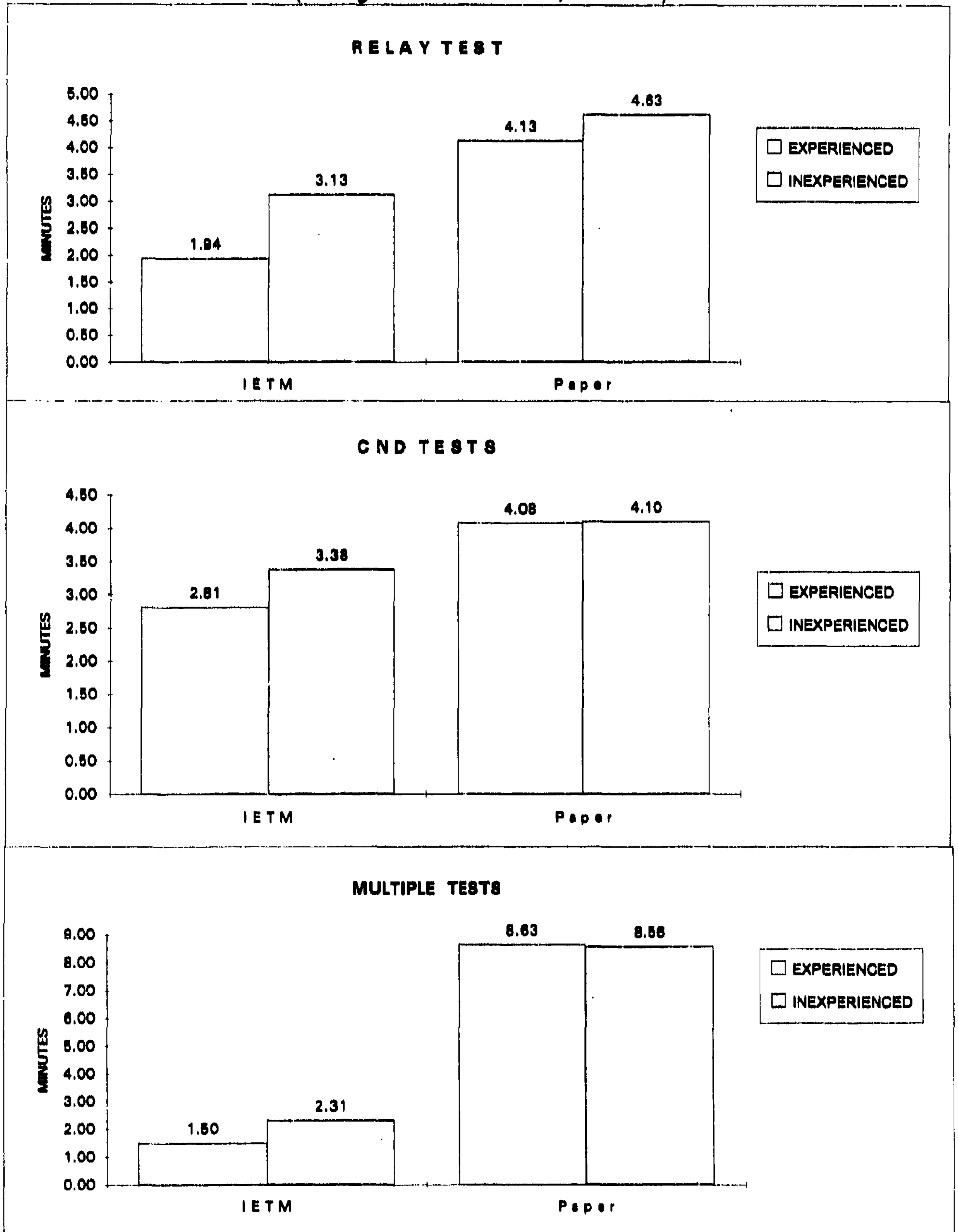


FIGURE 10

Comparison of Performance of Technicians Using IETMs with that of Technicians Using Paper TMs, for Maintenance Close-Out Interval (Average Times in Minutes; All Tests)

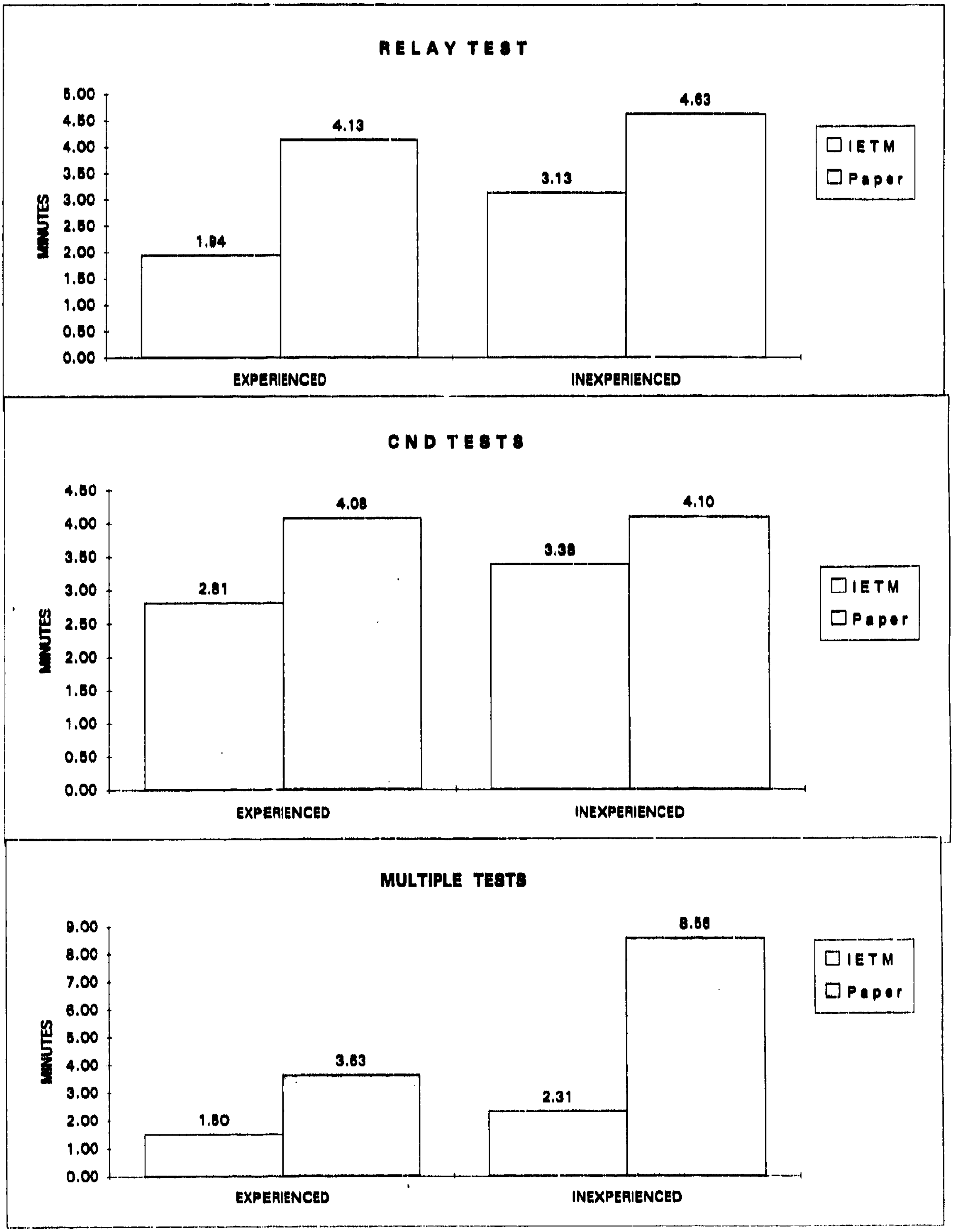


TABLE 11
Effect of Using IETMs Instead of Paper TMs in Preparation Interval (All Tests)

AVERAGES OF INDIVIDUAL RATIOS OF

$$\frac{\text{PERFORMANCE TIME (IETM)}}{\text{PERFORMANCE TIME (PAPER)}}$$

for each technician

	RELAY TESTS
Experienced Technicians	0.563
Inexperienced Technicians	0.839

	CND TESTS
Experienced Technicians	0.640
Inexperienced Technicians	1.011

	MULTIPLE TESTS
Experienced Technicians	0.199
Inexperienced Technicians	0.271

TABLE 12
TOTAL TIMES REQUIRED FOR RELAY TESTS USING IETMs
(ALL TECHNICIANS)

TECHNICIANS	- I N T E R V A L S -				TOTALS
EXPERIENCED	PREPARATION	FAULT-ISOLATION	PARTS-ORDERING	MAINTENANCE CLOSE-OUT	
S1	2	23	5	1	31.00
S2	3	49	11	1	64.00
S3	1	49.5	12	1	63.50
S4	3	32	7	2	44.00
S5	3	32	6	4	45.00
S6	2	61	6	2	71.00
S7	1	48	4	1	54.00
S12	2.5	27.5	5	3.5	38.50
AVERAGE TOTAL, EXPERIENCED TECHNICIANS:					51.38
INEXPERIENCED	PREPARATION	FAULT-ISOLATION	PARTS-ORDERING	MAINTENANCE CLOSE-OUT	
S9	2	59	5	6	72.00
S10	10	52	7	1	70.00
S11	6	43	10	3	62.00
S13	6	46	13	4	69.00
S14	1	46	6	3.5	56.50
S16	1	34	8	1.5	44.50
S17	2	31	10	3	46.00
S18	2	46	15	3	66.00
AVERAGE TOTAL, INEXPERIENCED TECHNICIANS:					60.75

TABLE 13
TOTAL TIMES REQUIRED FOR RELAY TESTS USING PAPER TMs
(ALL TECHNICIANS)

TECHNICIANS	- I N T E R V A L S -				TOTALS
EXPERIENCED	PREPARATION	FAULT-ISOLATION	PARTS-ORDERING	MAINTENANCE CLOSE-OUT	
S1	4	30	23	3	60.00
S2	4	35	24	1	64.00
S3	1	52	13	1	67.00
S4	2	39	6	4	51.00
S5	4	42	3	7	56.00
S6	6	46	9	5	66.00
S7	6	38	7	5	56.00
S12	4	33	8.5	7	52.50
AVERAGE TOTAL, EXPERIENCED TECHNICIANS:					59.06
INEXPERIENCED	PREPARATION	FAULT-ISOLATION	PARTS-ORDERING	MAINTENANCE CLOSE-OUT	
S9	6	61	34	8	109.00
S10	10	69	16	1	96.00
S11	3	45	5	3	56.00
S13	3	36	12	3	54.00
S14	12	35	11	5	63.00
S16	8	46	12	6	72.00
S17	6	61	22	5	94.00
S18	7	53	20	6	86.00
AVERAGE TOTAL, INEXPERIENCED TECHNICIANS:					78.75

TABLE 14
TOTAL TIMES REQUIRED FOR CND TESTS USING IETMs
(ALL TECHNICIANS)

TECHNICIANS	INTERVALS			TOTALS
EXPERIENCED	PREPARATION	FAULT-ISOLATION	MAINTENANCE CLOSE-OUT	
S1	14	55	2.5	71.50
S2	2	36	5	43.00
S3	3	51.5	5	59.50
S4	3	48	4	55.00
S5	1	26	1	28.00
S6	3	26	1	30.00
S7	2	22	3	27.00
S12	3	43	1	47.00
AVERAGE TOTAL, EXPERIENCED TECHNICIANS:				45.13
INEXPERIENCED	PREPARATION	FAULT-ISOLATION	MAINTENANCE CLOSE-OUT	
S9	3	55	7	65.00
S10	3	56	3	62.00
S11	2	52	2	56.00
S13	1	40	5	46.00
S14	2	26	1	29.00
S16	1	46	1	48.00
S17	3	39	3	45.00
S18	2	25	5	32.00
AVERAGE TOTAL, INEXPERIENCED TECHNICIANS:				47.88

Note: The CND Tests did not include a Parts-Ordering Interval.

TABLE 15
TOTAL TIMES REQUIRED FOR CND TESTS USING PAPER TMs
(10 TECHNICIANS)

TECHNICIANS	- I N T E R V A L S -			TOTALS
EXPERIENCED	PREPARATION	FAULT-ISOLATION	MAINTENANCE CLOSE-OUT	
S2	5	38	5	48.00
S4	4	60	3	67.00
S5	5	52	5	62.00
S6	3	68	3	74.00
S7	5	41	4	50.00
AVERAGE TOTAL, EXPERIENCED TECHNICIANS:				60.20
INEXPERIENCED	PREPARATION	FAULT-ISOLATION	MAINTENANCE CLOSE-OUT	
S11	4	31	2	37.00
S13	2	46	2	50.00
S14	7	41.5	4.5	53.00
S17	5	62	6	73.00
S18	4	42	6	52.00
AVERAGE TOTAL, INEXPERIENCED TECHNICIANS:				53.00

Note: The CND Tests did not include a Parts-Ordering Interval.

TABLE 16
TOTAL TIMES REQUIRED FOR MULTIPLE TESTS USING IETMs
(ALL TECHNICIANS)

TECHNICIANS	- I N T E R V A L S -				TOTALS
EXPERIENCED	PREPARATION	FAULT-ISOLATION	PARTS-ORDERING	MAINTENANCE CLOSE-OUT	
S1	2	51	12	1	66.00
S2	2	55	9	2	68.00
S3	2	102	7	1	112.00
S4	3	45	12	1	61.00
S5	1	26	8	1	36.00
S6	2	64	9	1	76.00
S7	5	71	10	2	88.00
S12	2	44	8	3	57.00
AVERAGE TOTAL, EXPERIENCED TECHNICIANS:					70.50
INEXPERIENCED	PREPARATION	FAULT-ISOLATION	PARTS-ORDERING	MAINTENANCE CLOSE-OUT	
S9	4	55	16	4	79.00
S10	2	71	14	1	88.00
S11	2	65	13	3	83.00
S13	4	56	10	3	73.00
S14	2	59	18	0.5	79.50
S16	1	47	10	4	62.00
S17	2	39	10	1	52.00
S18	1	90	16	2	109.00
AVERAGE TOTAL, INEXPERIENCED TECHNICIANS:					78.19

TABLE 17
TOTAL TIMES REQUIRED FOR MULTIPLE TESTS USING PAPER TMs
(ALL TECHNICIANS)

TECHNICIANS	-I N T E R V A L S-				TOTALS
EXPERIENCED	PREPARATION	FAULT-ISOLATION	PARTS-ORDERING	MAINTENANCE CLOSE-OUT	
S1	4	63.5	21	6	94.50
S2	5	106	9	8	128.00
S3	13	62	17	16	108.00
S4	2	67	33	8	110.00
S5	6	63	22	6	97.00
S6	6	66	27	4	103.00
S7	13	87	26	14	140.00
S12	5	96	29.5	7	137.50
AVERAGE TOTAL, EXPERIENCED TECHNICIANS:					114.75
INEXPERIENCED	PREPARATION	FAULT-ISOLATION	PARTS-ORDERING	MAINTENANCE CLOSE-OUT	
S9	3	113	26	8	150.00
S10	12	155	29	8	204.00
S11	8	78	20	10	116.00
S13	10	76	14	8	108.00
S14	4	59	17	8	88.00
S16	4.5	102.5	22.5	8.5	138.00
S17	7	77	36	9	129.00
S18	3	64	35	9	111.00
AVERAGE TOTAL, INEXPERIENCED TECHNICIANS:					130.50

FIGURE 11

Comparison of Performance of Experienced Technicians with that of Inexperienced Technicians, for Total Test Performance Times (Average Total Times in Minutes Required; All Tests)

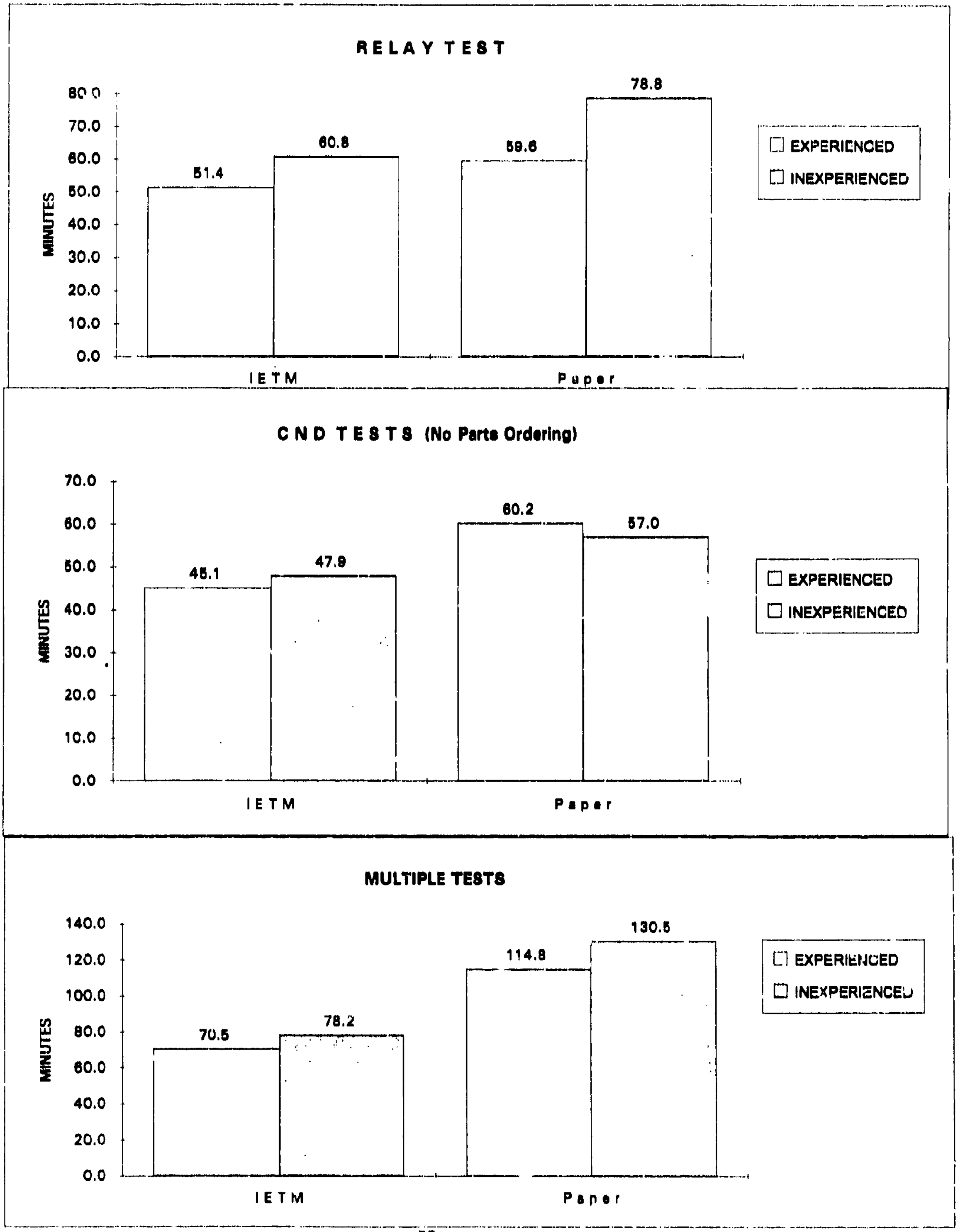


FIGURE 12

Comparison of Performance of Using IETMs with that of Technicians Using Paper TMs, for Total Test Performance Times (Average Total Times in Minutes Required; All Tests)

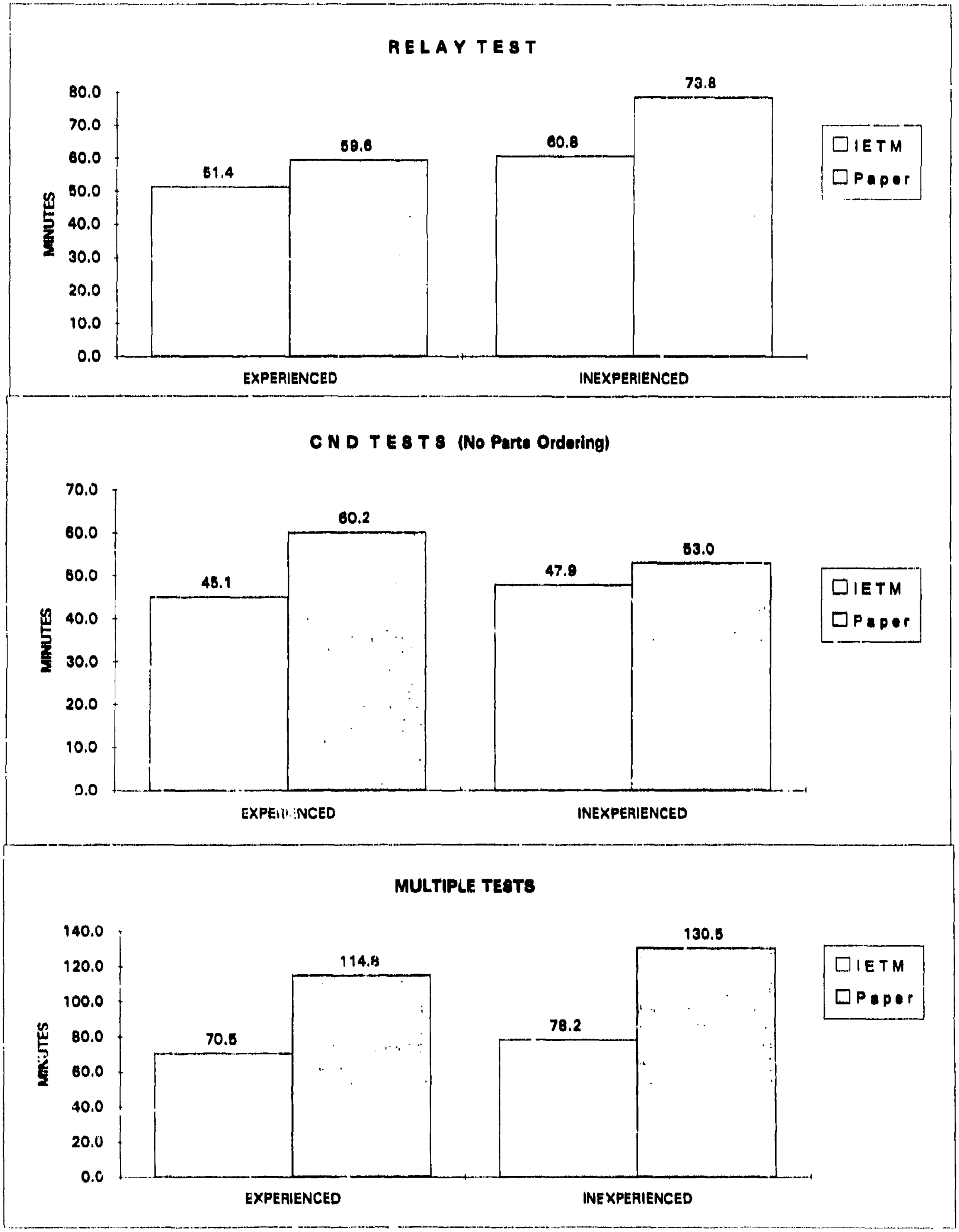


TABLE 18

EFFECT OF USING IETMs INSTEAD OF PAPER TMs: TOTAL TEST PERFORMANCE TIMES (ALL TESTS)

Ratios of Total Times Required Using IETMs to Total Times Required Using Paper TMs

TECHNICIANS	RELAY TEST			CAN NOT DUPLICATE (CND)			MULTIPLE TEST		
	Total Times Using			Total Times Using			Total Times Using		
EXPERIENCED	IETM	Paper	RATIO	IETM	Paper	RATIO	IETM	Paper	RATIO
S1	31	60	0.517	71.5	--	--	66	94.5	0.698
S2	64	64	1.000	43	48	0.896	68	128	0.531
S3	63.5	67	0.948	59.5	--	--	112	108	1.037
S4	44	51	0.863	55	67	0.821	61	110	0.555
S5	45	56	0.804	28	62	0.452	96	97	0.990
S6	71	66	1.076	30	74	0.405	76	103	0.738
S7	54	56	0.964	27	50	0.540	88	140	0.629
S12	38.5	52.5	0.733	47	--	--	57	137.5	0.415
	RATIO AVERAGE:		**0.863**	**RATIO AVERAGE:**		**0.623**	**RATIO AVERAGE:**		**0.699**
	Total Times Using			Total Times Using			Total Times Using		
INEXPERIENCED	IETM	Paper	RATIO	IETM	Paper	RATIO	IETM	Paper	Ratio
S9	72	109	0.661	65	--	--	79	150	0.527
S10	70	96	0.729	62	--	--	88	204	0.431
S11	62	56	1.107	36	37	0.973	83	116	0.716
S13	69	54	1.278	46	50	0.920	73	108	0.676
S14	56.5	63	0.897	29	53	0.547	79.5	88	0.903
S16	44.5	72	0.618	48	--	--	62	138	0.449
S17	46	94	0.489	45	73	0.616	52	129	0.403
S18	66	86	0.767	32	52	0.615	109	111	0.982
	RATIO AVERAGE:		**0.882**	**RATIO AVERAGE:**		**0.734**	**RATIO AVERAGE:**		**0.636**

TABLE 19

Effect of Using IETMs Instead of Paper TMs
on Total Test-Performance Times

SUMMARY OF RATIOS OF
INDIVIDUAL TECHNICIAN PERFORMANCE TIMES
FROM TABLE 18 (ALL TESTS)

	RELAY TESTS
Experienced Technicians	0.863
Inexperienced Technicians	0.882

	CND TESTS
Experienced Technicians	0.623
Inexperienced Technicians	0.734

	MULTIPLE TESTS
Experienced Technicians	0.699
Inexperienced Technicians	0.636

TABLE 20
INCIDENCE OF PROCEDURAL ERRORS
(ALL TESTS)

TECHNICIANS	RELAY		CND		MULTIPLE	
EXPERIENCED	IETM	Paper	IETM	Paper	IETM	Paper
S1	0	2	1	1 + 1 FI	0	2
S2	1	0	1	0	0	0
S3	2	3	0	1 + 1 FI	4 + 1 FR	1
S4	1	0	0	1	0	2
S5	0	1	0	0	1 + 1 FR	1
S6	0	3 + 1 FR	0	1	0	2
S7	2	0	0	0	0	1 + 1 FR
S12	0	0	1	1 + 1 FI	0	1
TOTALS:	6	9	3	5	5	10
INEXPERIENCED	IETM	Paper	IETM	Paper	IETM	Paper
S9	1 + 1 FR	0	0	1 + 1 FI	0	2
S10	0	0	0	VOID	0	0
S11	1	1 + 1 FR	0	0	1	0
S13	0	0	0	0	0	1
S14	0	0	0	0	0	0
S16	0	0	0	1 + 1 FI	0	3
S17	1	1	0	0	0	0
S18	1	2	0	1	0	1
TOTALS:	4	4	0	3	1	7

FI = Failure to Identify the Fault. FR = False Removal

4.1.2.1 Procedural Errors

A Procedural Error is defined as a serious misuse of the procedures, e.g., technician may perform a test on the wrong pin and, as a result, branch to an improper sequence. Table 20 presents the number of these types of errors as a function of technician experience level, of fault type, and of medium.

4.1.2.2 Success in Isolating the Fault

The IETM/PMA medium was used to support Fault Isolation in 48 cases; the paper medium was used in 47 cases. (One of the tests involving a paper TM [Technician S10, CND test] was voided because of a test protocol error.) In the Relay and Multiple Tests, all Fault Isolations were successfully performed by both Experienced and Inexperienced Technicians with both TI media. For the CND tests, the correct result was a determination that the symptoms presented could not be duplicated: using the IETM/PMA combination, all Technicians arrived at the correct result; with paper TMs, three of the Experienced Technicians and two of the Inexperienced Technicians failed to arrive at the correct result. Thus, there were a total of 5 failures to Fault-Isolate out of 95 tests, all using the paper TM.

4.1.2.3 False Removals

In Fault Isolations and Corrective Maintenance, a False Removal is declared when a technician replaces and then sends to the Intermediate Maintenance Activity (IMA) a part he believes to be faulty but in fact testing at IMA shows the part to be good. During this Test, when a Technician identified a part that he believed to be the cause of the fault but in fact was not, the technical observer "simulated" the replacement and told the Technician to proceed with usual practice, e.g., a "System-Health Check". Of course, the check showed the same symptom; whereupon the technical observer declared a False Removal and the observer directed the Technician to resume troubleshooting. IETM/PMA users and the paper TM users committed 3 False Removals each. The incidence of these False Removals is shown on Table 20.

5.0 EVALUATION OF PERFORMANCE RESULTS

5.1 GENERAL CONSIDERATIONS

As stated in section 1, this field test was carried out to evaluate a number of innovations in IETM technology which have been developed and evaluated in the laboratory under the USAF IMIS program (see section 1.3). The final assessment of any such technological advances depends, of course, on their use by active technicians at an operational base using operational aircraft. Measures of their effectiveness in the field, as noted in section 4.1, are:

a. Comparisons of (1) times required to carry out specific Fault-Isolation tasks supported by an IETM with (2) performance times when the same technician (or one with similar experience) carries out the same type of Fault-Isolation task using a paper TM for support of his effort.

b. Comparison of (1) number of errors occurring when the technicians are supported by IETMs with (2) the number of errors occurring when the technicians are supported by paper TMs.

Additionally, in evaluating the usability and operational suitability of such innovations, a careful recording of technicians' reactions is critical. Thus, even though a given approach may be made to work in the field (in a specific test), it must be abandoned or modified if it makes the technicians' job significantly more difficult, or significantly increases training requirements. Moreover, such comments are of great importance in pointing out approaches to improving the processes and design of the processes under evaluation.

5.1.1 Summary of Previous Test Results

As noted, previous field tests performed by the Navy and Air Force, with a variety of hardware systems, have consistently shown significant improvement in technician performance when TI was displayed in IETM form. In every case, technicians were overwhelmingly in favor of the IETM approach as compared with the use of paper TMs, even though, in every case, a number of criticisms and proposals for improvement of the IETM were provided.

Qualitatively, the following principles were demonstrated by these tests:

a. Improvement in performance was greater for inexperienced technicians than for experienced technicians.

b. Improvement in performance was greater for more complex systems and procedures (e.g., Fault Isolation) than for simpler, more straightforward procedures (e.g., a simple remove-and-replace Corrective-Maintenance action).

Consequently, the data have been displayed in section 4 to compare the effects of adopting IETMs as a function of technician experience.

5.1.2 Limitations on Interpretations of Results

In essentially all populations of test subjects, there were one or two subjects whose performance was <u>much</u> worse than the rest, and one or two whose performance was <u>much</u> better than the rest. Such atypical competence is, of course, common in real situations. In the present tests, to make behavior of this type more visible, each individual result of each of the 16 Technicians has been displayed for each of the six tasks performed. Average performance times for each group also have been displayed, but the wide distribution noted in this limited population, although conclusive in demonstrating <u>overall</u> improvement in performance, calls into question the validity of using these data in a statistical or quantitative sense for predictive purposes.

Similarly, of course, the differences in the types of tests performed, in the types of faults introduced, in the quality of the IETM material prepared for each test, and in technician experience, makes impossible the use for general predictive purposes of data averaged over more than a single test group (with its unique combination of technician experience, test type, test interval, and medium).

5.1.3 Summary of Technician Performance

The most significant test Intervals were the Fault-Isolation Interval and the Parts-Ordering Interval. Tables 16 and 17 show the fractions of total test time occupied by these test-interval times, for all test subjects and for all tests.

5.1.3.1 Relative Fault-Isolation Effectiveness

For the Fault-Isolation Interval, Table 6 shows relative performance times of Technicians using IETMs as compared to those using paper TMs, for each test group.

In every case, performance times were reduced by the introduction of IETMs, except for the group of Experienced Technicians performing the Relay Tests, in which performance times were essentially equal for the two media. The relative performance times for the two media for all test groups are displayed in Figure 5. Note that for Inexperienced Technicians, introduction of IETMs reduced Multiple-Test Fault-Isolation time by about one third.

Figure 5 shows that in four of the six test-type/medium combinations, Experienced Technicians performed the troubleshooting assignment in less time that the Inexperienced Technicians; but in performing the CND tests with paper TMs, Experienced Technicians took about 16% longer than did Inexperienced Technicians.

5.1.3.2 Relative Parts-Ordering Effectiveness

It is noted that for the Parts-Ordering Test Interval, the performance times consisted of the times required to locate the information needed to order the parts and to complete the appropriate section of the VIDS/MAF form. However, in the case of the IETM/PMA combination, the time involved in the automated completion of the form was sufficiently brief and constant, as compared with the time required to assemble the information, that it was not reported. In the case of the paper-TM, the form-preparation portion of the Parts-Ordering Interval (which was included in the recorded Parts-Ordering performance times) was a significant part of the overall time required. Any direct comparisons of performance time should, therefore, be made with this factor in mind.

For the Parts-Ordering Interval, **Table 8** shows that average performance times were decreased in every case in going from paper TMs to IETMs.

In the case of the Multiple Tests, Table 8 shows that average performance time for Experienced Technicians was reduced by more than 50%.

5.2 TECHNICIANS' RATING OF EFFECTIVENESS OF IETM/PMA FEATURES

As described in section 3.8.1e, all sixteen Technicians (eight Inexperienced and eight Experienced), after test performance, filled out User Evaluation Questionnaires in which they rated the effectiveness of various features of the IETM/PMA combination. The forms used are reproduced in Appendix D. Features rated were of two types:

a. Physical Features of the IETM/PMA Combination (15 Items). [See section 5.2.1]

b. Software/Operational Features (25 Items). [See section 5.2.2]

Each of these features was rated by each Technician according to the scale shown in Table 21.

TABLE 21. Rating Scale Used in Technicians' Evaluation of IETM/PMA Physical Features and Software/Operational Features

Scale Value	Scale Definition
0	Unsatisfactory
1	Marginal
2	Satisfactory
3	Highly Satisfactory
4	Outstanding
—	Can't Evaluate

Technicians' ratings were averaged separately for the Inexperienced Group and for the Experienced Group. Thus, an average rating of 0 would imply that all the members of the group found the particular feature Unsatisfactory, the lowest possible rating, whereas a rating of 4.0 would indicate that all Technicians found the feature Outstanding. Technician responses were, of course, subjective, but were based on Technicians' opinions as to the suitability of a given feature in contributing to the Fault Isolation and Maintenance reporting tasks they had just performed.

5.2.1 Physical Features of the IETM/PMA Combination

Table 22 presents ratings (scale value averages) for the 15 Physical Features of the IETM/PMA which were evaluated.

Table 23 summarizes the distribution of ratings for Inexperienced and Experienced Technicians for the 15 features evaluated.

Note that <u>all</u> features were rated <u>at least</u> <u>Satisfactory</u> by all Technicians, with 67% (by Inexperienced) and 87% (by Experienced) rated as Highly Satisfactory or between Highly Satisfactory and Outstanding.

The lowest rated features (between Satisfactory and Highly Satisfactory) were:

4. Ease of positioning/repositioning PMA at worksite	2.75/3.0.
9. Response time after key press	2.125/2.375
10. Appropriateness of function keys	2.87/3.0
14. Glare on display screen	2.625/2.71
15. Key pressure resistance/sensitivity	2.625/3.125

Dissatisfaction with these features (amplified by Technicians' oral and written comments) clearly indicates the need for the incorporation of functional improvements in certain features of the IETM/PMA design.

Response time (Feature 9) was on occasion as high as 5-8 seconds. Dissatisfaction with such a delay time in displaying of the next screen has been expressed on all previous field tests, but the incorporation of other functional improvements in the version of the hardware and software used during this test unfortunately failed to correct this condition. Response-time specifications for an IETM/PMA combination require response (full display of next screen) in no greater than 1 second.

The Glare rating referred to use of the Liquid Crystal Display with the backlighting turned off. A position switch which provided screen backlighting eliminated the problem. Data were taken with screen lighting on or off, as considered desirable by the individual technicians.

TABLE 22. Technicians' Evaluations of Effectiveness of Selected Features of the IETM/PMA Combination

	Feature Evaluated	Scale Value Average Inexperienced Technicians	Scale Value Average Experienced Technicians
1.	Overall weight of the device	3.375	3.625
2.	Overall size (width & length of the device)	3.25	3.5
3.	Overall height (thickness of the device)	3.125	3.375
4.	Ease of positioning/repositioning PMA at worksite	2.75	3.0
5.	Ease of connecting PMA to the 1553 bus	3.5	3.875
6.	Size of keys	3.62	3.5
7.	Location of keys	3.375	3.375
8.	Spacing of keys	3.25	3.5
9.	Response time after key press	2.125	2.375
10.	Appropriateness of function keys	2.87	3.0
11.	Adequacy of screen size for displaying information	3.5	3.375
12.	Brightness of screen	3.62	3.25
13.	Contrast between letters/graphics and background	3.375	3.37
14.	Amount of glare on display screen	2.625	2.71
15.	Key pressure resistance/sensitivity	2.625	3.125

TABLE 23. Categorization of Technicians' Ratings of Physical Features of the IETM/PMA Combination

Category	Inexperienced Technicians	Experienced Technicians
Satisfactory - Highly Satisfactory	5	2
Highly Satisfactory		2
Highly Satisfactory - Outstanding	10	11
TOTAL	15	15

5.2.2 Software-Operational Features of the IETM/PMA Combination

Table 24 presents the averaged ratings for the 25 IETM/PMA Software/Operational Features evaluated.

Table 25 summarizes the distribution of ratings for Inexperienced and Experienced Technicians for the 25 features evaluated.

All features were rated at least Satisfactory, with 72% of them rated as Highly Satisfactory or between Highly Satisfactory and Outstanding, by both Inexperienced and Experienced Technicians.

The features rated lowest (Satisfactory or between Satisfactory and Highly Satisfactory)

by both groups of Technicians were:

22. Ease of moving cursor with arrow keys	2.87/3.25
24. Ease of moving cursor with thumb knob	2.00/2.50
25. Ease of returning to appropriate place in a set of procedures after branching elsewhere in data base	2.00/2.50
27. Appropriate number of procedural steps per screen	2.87/2.625
29. Scrolling function availability	2.875/2.86
30. Scrolling mode (hard key)	2.875/2.83
31. Scrolling with arrow keys and SELECT key	3.00/2.86
35. Cursor visibility	2.75/3.125
38. Ease of accessing locator diagrams	3.25/2.875
40. Adequacy of wiring diagrams	3.105/2.875

TABLE 24. Technicians' Evaluations of Effectiveness of Selected Software/Operational Features of the IETM/PMA Combination

	Feature Evaluated	Scale Value Average Inexperienced Technicians	Scale Value Average Experienced Technicians
16.	Spacing of information on the screen (vs crowding)	3.25	3.25
17.	Legibility of displayed letters, numbers, and words	3.5	3.125
18.	Adequacy of organization/arrangement of information	3.375	3.125
19.	Adequacy of options on menus/function keys	3.14	3.250
20.	Adequacy of menu organization	3.29	3.250
21.	Ease of using menus/function keys	3.57	3.125
22.	Ease of moving cursor with arrow keys	**2.87**	3.25
23.	Ease of moving cursor by pressing number keys	3.0	3.14
24.	Ease of moving cursor with thumb knob	**2.00**	3.17
25.	Ease of returning to appropriate place in a set of procedures after branching elsewhere in data base	**2.00**	**2.50**
26.	Adequacy of information for supporting maintenance tasks (i.e., completeness, accuracy, relevance)	3.00	3.12
27.	Appropriate number of procedural steps per screen	**2.87**	**2.625**
28.	Adequacy of PMA for completing supply requisitions, VIDS/MAFs, etc.	3.87	3.37
29.	Scrolling function availability	**2.875**	**2.86**
30.	Scroll mode (hard key)	**2.875**	**2.83**
31.	Scrolling with arrow keys and SELECT key	3.00	2.86
32.	Availability of functions on soft keys	3.00	3.00
33.	Menu item names	3.14	3.125
34.	Availability of menu functions	3.00	3.125
35.	Cursor visibility	**2.75**	3.125
36.	Legibility of graphics	3.57	3.125
37.	Adequacy of detail on graphics	3.50	3.125
38.	Ease of accessing locator diagrams	3.25	**2.875**
39.	Adequacy of detail provided on locator diagrams	3.25	3.00
40.	Adequacy of wiring diagrams	3.105	**2.875**

TABLE 25. Categorization of Technicians' Ratings of Software/Operational Features of the IETM/PMA Combination

Category		Inexperienced Technicians	Experienced Technicians
Satisfactory		2	
Satisfactory - Highly Satisfactory		5	7
Highly Satisfactory		5	2
Highly Satisfactory - Outstanding		13	16
	TOTAL	25	25

Although, as noted, all of these features were rated at least Satisfactory, Technicians were less enthusiastic about the following aspects of the IETM/PMA combination than they were about other IETM/PMA software/operational factors:

a. **Cursor operation (22, 24, 35).** Careful attention will be given in future PMA designs to cursor configuration and operation to improve this aspect of the PMA operation.

b. **The Scrolling function (29, 30, 31).** The introduction of a scrolling function into a small PMA is a difficult design problem, both from the standpoint of the mechanics to produce the scrolling and from the standpoint of satisfactory display (e.g., of drawings or diagrams too large for single-screen display). Work is being carried out both on improvement of scrolling itself, and on the development of display methods which will obviate the need for scrolling altogether.

c. **Special aspects of IETM design (27, 38, 39).** These ratings, together with a number of oral comments concerning various aspects of the quality of the displayed Technical Information, indicate the need for improvement of TI quality as it relates to small-screen display, especially in the areas of graphics and text-graphics interfaces. At this time, there appears to be a trade-off between the extent of the use of automation in preparing the TI (a number of approaches to TI automation were field-tested for the first time during this test) and the user-friendliness of the finished IETM. The IETM-preparation process must be refined to optimize IETM utility, even at the cost of more complex automated preparation techniques or less automated procedures requiring greater author involvement in the process.

d. **Ability to return to a specific point in the procedure after branching (25).** (In spite of this relatively low rating, no comments concerning this feature were made during the oral debriefing sessions.) This capability will be reviewed to determine whether problems exist in this function as designed; i.e., whether the PMA fails to return, or returns slowly, to its prebranch point on request.

5.3 EVALUATION OF KEY ELEMENTS OF THE IETM/PMA COMBINATION

This Section summarizes technical evaluations reported by both Test Observers and Technicians on various aspects of the IETM/PMA design and operation.

5.3.1 The BIT-IETM/PMA Interface Using the 1553 Bus

The BIT-IETM/PMA interface allows the technician to use the PMA to interact with and control the F/A-18 BIT for the Flight Control System. This BIT control capability requires the technician to install an electrical cable connecting the PMA to the aircraft's 1553 multiplex bus. During the test, the main uses of this capability involved the Memory Inspect (MI) and Test Group (TG) procedures.

Two bases were used to evaluate this direct BIT access capability of the PMA:

a. Test-observers' evaluations of its effectiveness during the 48 Fault-Isolation tasks in which it was used.

b. Technicians' debriefing comments on the IETM/PMA-BIT interface.

5.3.1.1 <u>Summary of Observers' Evaluations</u>

The IETM/PMA control of BIT worked well throughout the test, including the hookup and operability test as well as its use in conducting TG and MI procedures. The following occurrence is an example of its utility: One of the Fault-Isolation procedures called for a particular TG procedure whose outcome should have been a particular BIT Logic Inspection (BLIN) code. However, after BIT ran the TG procedure commanded by the IETM/PMA, the PMA displayed a BLIN code different from the expected one. Suspecting a problem with the IETM/PMA or the 1553 interface, the interface was disconnected and the TG procedure was rerun using the aircraft's DDIs and FCCs (neither the PMA nor its interface with BIT was active). The test result without the PMA/1553 interface was the same as with IETM/PMA/1553 interface meaning that the aircraft had a non-test fault (an activator failure) and the IETM/PMA, working with the FCS's BIT through the 1553 interface, had detected it. Instances of a similar nature occurred, involving generator overheat and pin damage in cable connectors. These instances are interpreted as evidence that the BIT-1553-IETM/PMA interface provided valid results.

5.3.1.2 <u>Summary of Technicians' Debriefing Comments</u>

Technicians' overall opinion of the 1553 interface was positive although some suggestions were made for improvement. (Technicians' comments on all phases of the Test are presented in detail in Appendix A.)

a. The positive aspects included:

(1) Data displays were more readable, and less cluttered on the PMA than on the aircraft's DDIs.

(2) Automated assessments of Memory Inspect numbers were far easier and far more accurate than the manual assessments.

b. Negative aspects included:

(1) The electrical cord was an impediment to Technician mobility.

(2) The process via the PMA/BIT interface was slower than the direct manipulation of cockpit controls.

(3) Information to be compared was displayed on two screens introducing unnecessary difficulty.

5.3.2 The Portable Maintenance Aid (PMA)

A Human Factors review of the PMA hardware raised 24 issues regarding the PMA design. The more troublesome issues are noted below:

a. It is difficult to move the cursor among non-adjacent, non-aligned areas.

b. There are too many methods for moving the cursor and pointer.

c. The utility of user-controllable font size is questionable.

d. Viewing angle is restricted by the PMA bezel.

e. Confusion exists among the alternative methods of selecting options displayed on the screen.

5.3.3 IETM/PMA Presentation Features Considered Effective

a. Integration of Information:

(1) Side-by-side text and supporting graphics.

(2) Linking to cross references to branching procedures.

(3) Ability to call locator graphics; e.g., accessed via Required Conditions or a soft key.

b. Automated Functions:

(1) Automation of VIDS/MAF completion (especially the Parts-Ordering section).

(2) Ability to perform Memory Inspect.

(3) Control of the FCS BIT via the 1553 multiplex bus.

c. Error Prevention/Reduction:

(1) Regaining place in a procedure after interruption.

(2) Dropping a row when moving to the right to get the "Go To" instruction.

d. PMA Portability (Size and Weight).

e. Level of TI detail.

f. Displays only that information relevant to the Technician's assigned aircraft.

5.3.4 Suggestions to Further Improve IETM/PMA (not in order of importance)

a. Provide a browse mode for work planning (i.e., a capability for a Technician to scan through maintenance procedures available in the IETM/PMA, and review information-access paths and navigation instructions).

b. Speed up PMA's response time.

c. Provide procedures for pre-expended parts.

d. Provide additional locator information on wiring diagrams.

e. Provide both abbreviated wiring diagrams and schematics.

f. Provide lockout to prevent inadvertent key activation.

g. Reduce screen glare when not "backlit".

h. Make PMA less awkward in cockpit.

i. 1553 interface:

(1) Should be applied so as not to disable the mission computers which in turn disabled the Digital Display Indicators (DDIs).

(2) Improve the Nosewheel Well location of the interface plug.

(3) Design so that the 1553 umbilical cord does not affect PMA portability.

(4) Consolidate feed from the data bus to the PMA into one vs two screens.

j. Standardize location of watch icon.

k. Eliminate cursor expectancy violations.

l. Provide alerts for upcoming series of checks.

m. Ease access to important information.

(1) Initial set up.

(2) Fault identification.

(3) Completing the VIDS/MAF.

n. Standardize on one means of cursor control.

o. Use a 1-0 (not the 0-9) sequence for number keys.

p. Establish consistency with operational practices; e.g., those involving external hydraulic generators and preparation of the VIDS/MAFs for the multiple faults.

q. Design friendly abort and restart procedures.

r. Arrange so that there is no IETM/PMA advance until CDI sign off.

s. Eliminate confusing similarities among required conditions, follow-on and closing actions.

t. Provide more precise uses for the diagnostic block diagram.

u. Ruggedize the PMA; increase the PMA capability of withstanding harsh environmental conditions.

v. Provide better labelling of soft function keys.

w. Provide better battery life and recharge procedure.

x. During a maintenance procedure, present a record of the time spent on the procedure so far, as compared with norm or total.

y. Simplify the highlight and select functions.

z. Reduce Redundancy in Function Keys.

aa. Suggestions for Additional Integration. Although the Navy and Air Force are already pursuing many of the Technicians' suggestions, the suggestions are reported here as a field endorsement of these programs.

(1) Provide link to Maintenance Control (MC).

(2) Provide next day's flight schedule.

(3) Provide an interface between the PMA and the Data Storage Unit (DSU).

(4) Add training content to the IETM Data Base.

5.3.5 Suitability of the PMA for Fleet Use

Results for this Test have shown that the Air-Force-developed PMA was very suitable for the application for which it was intended. However, for Fleet use (operation of aircraft from carriers), certain improvements are needed, as identified by the users cited in this Section and in Appendix A; e.g.,

improved cabling for external connection (1553 bus or external power) so as not to impede device portability, better cursor/pointer control (such as a mouse), longer battery life and unobtrusive battery charging, less glare from screen, greater ruggedness, suggested relabeling of function keys. These complaints will generally apply to any portable display device now commonly available in the market place.

Fleet use of PMAs would impose additional requirements such as incorporation of an interface to the Navy SNAP and NALCOMIS Programs, a diagnostic application, or a training module, all of which have been developed by other activities. Such applications can be performed with available commercial software such as MS/DOS and MS/Windows, operating with an INTEL X86 chip set. The PMA used in this Test employs a Motorola CPU and a DOS-incompatible operating system. Although ruggedized to some extent, the Air Force PMA does not meet MIL-E-16400 requirements for the high-humidity and salt-spray environments encountered in shipboard operations.

Thus, Navy requirements for PMAs (PEDDs) might include some ruggedized COTS devices (even less rugged than the Air Force PMA) and some very rugged MILSPEC devices, effectively bracketing the capability of the AF PMA in this regard. The memory capability of the PMA, both RAM and nonvolatile, is very low compared with available commercial norms. The Navy device would require 8 or 10 MByte RAM and several hundred MByte nonvolatile storage, vs the 6/32 MByte allocation of the Air Force PMA. The packet radio on the Air Force device is undesirable in the EMI-sensitive environment of Navy use.

In summary, the factors discussed above lead to the conclusion that the Air Force PMA, although very capable, would not, in its present form, be suitable for the Fleet. A more extensive evaluation would involve additional factors.

5.4 TECHNICIAN PREFERENCE FOR THE IETM/PMA COMBINATION COMPARED TO PAPER TECHNICAL MANUALS

This Section summarizes Technician preferences for various aspects of the IETM/PMA combination as compared with the NAVAIR-based work-package F/A-18 Technical Manuals.

5.4.1 Evaluation of Technician Preference for IETM/PMA vs Paper TMs

Section 3 of the User Evaluation Questionnaire (see Appendix D) consisted of a rating form which solicited a comparative assessment of the IETM/PMA with respect to the standard NAVAIR paper-based TMs. Table 26 shows the rating scale used.

TABLE 26. Rating Scale Used in Technicians' Comparative Evaluation of IETM/PMA and Paper TM Characteristics

Scale Value	Scale Definition
0	Paper TM Significantly Better
1	Paper TM Slightly Better
2	No Difference
3	IETM/PMA Slightly Better
4	IETM/PMA Significantly Better
—	Can't Evaluate

Technicians' preference was evaluated from eight standpoints (questions 41-48 of the User Evaluation Questionnaire). All sixteen Technicians (eight Inexperienced and eight Experienced) filled out the rating form. Results are shown in Table 27 as averaged scale factors for each group.

As shown in previous field tests, both groups of Technicians preferred the IETM/PMA combination to the use of paper TMs for use in F/A-18 troubleshooting. Particularly appealing to the Technicians is the ability to obtain required Technical Information without the need to search through many pages (or volumes) of conventional paper-based Technical Manuals (e.g., questions 41, 42, 43). Technicians were somewhat less enthusiastic about the actual presentation of the TI itself (questions 44 [Inexperienced], 47, 48). As noted in section 5.2.2, additional work is required to optimize for the user the actual display of Technical Information, and exploit the capability of a luminescent screen to provide a Technician with more effective maintenance support information.

TABLE 27.
Technicians' Preference for IETM/PMA
Compared with F/A-18 Paper-Based Technical Manuals, General Features

	Features	Average Ratio Inexperienced	Average Ratio Experienced
41.	The overall time and effort required to obtain maintenance information	3.875	3.375
42.	The fatigue you experience when using it	3.375	3.375
43.	The confusion or frustration you experienced in obtaining needed Technical Information	3.25	3.375
44.	The overall organization and arrangement of Technical Information	2.75	3.375
45.	Obtaining access to needed Technical Information	3.125	3.25
46.	The method of presenting Technical Information	3.125	3.25
47.	The overall completeness, accuracy, and applicability of Technical Information	2.375	2.75
48.	Supporting maintenance on the F/A-18 flight control system	2.57	2.50

6.0 RECOMMENDATIONS

As a result of the present evaluation by the Navy and Air Force participants in the preparation and field testing of IETMs based on the latest IMIS technology, the following actions are recommended:

6.1 REVIEW OF METHODS FOR AUTOMATED PREPARATION OF IETMs

6.1.1 Preparation of IETM for Test

In the present Test, the IETM provided to the using Technicians was prepared through creation of an IETM Data Base, by the McDonnell Aircraft Co. This IETMDB was generally in accordance with the Air Force Content Data Model (CDM), as described in the DOD IETMDB Specification MIL-D-87269 (which, however, was not yet published at the time). The actual IETM material (i.e., translation of the IETMDB to the material actually displayed) was composed through the use of techniques that were almost entirely automated, with the software (the Presentation System) hosted in the PMA itself.

6.1.2 Evaluation of IETM Preparation Process

Comments as to the effectiveness of the IETM preparation process were obtained from three sources:

a. The experience of the AF Contractor in preparing the IETMDB used (based on NAVAIR F/A-18 paper TMs),

b. The experience of the Armstrong Laboratory (AL/HRGO) in converting this material to IETM form, and

c. Test Technicians and Test Observation personnel, based on the results of user performance with, and preference for, the Technical Information.

6.1.3 RECOMMENDATIONS

Based on evaluation of these sources, the following efforts with respect to IETM preparation are recommended.

a. IETMDB requirements given in MIL-D-87269 should be carefully reviewed from the standpoints of:

(1) adequacy in supporting the preparation of optimal IETMs, either by means of automated techniques or by an author, or by a combination of both; and

(2) practicality for preparation of the IETMDB to achieve completeness without unnecessary effort or complexity.

b. Available procedures for preparation of IETMDBs in accordance with MIL-D-87269 should be carefully reviewed. A procedural Guide for such preparation, for the guidance of Contractors and DOD System Acquisition Managers, should be prepared and promulgated. (The DOD-established Tri-Service IETM Working Group is preparing such a document, completion of which is currently scheduled for the first quarter of FY 1995.)

c. Further evaluation is required to determine the extent to which IETMDB information so prepared can be extracted, compiled, ordered, and formatted for viewing by a technician, through use of a Presentation System of the IMIS type (i.e., "dynamically", by the software hosted in the PMA), without loss of effectiveness and user friendliness. (See note in section 5.2.2.)

d. Procedures for Validation of IETM Technical Information in the IETMDB and TI at the Presentation System level, prepared from thr IETMDB by automated techniques, should be developed in accordance with MIL-Q-87270 of 20 Nov 1992, ***Quality Assurance Program: Interactive Electronic Technical Manuals and Associated Technical Information; Requirements for*** (ref. 16). Such procedures should be standardized and incorporated into an updated version of MIL-Q-87270.

6.2 IMPROVEMENTS IN PMA CAPABILITY

The effectiveness of a PMA in aircraft maintenance has been clearly demonstrated by this Test. However, further action should be taken, particularly from the standpoint of human factors (user-interaction) and environmental/ruggedness characteristics, to improve the device to make it more effective in operational situations. A Tri-Service set of standard performance requirements for the PMA (or PEDD), similar to those expressed in MIL-D-87269 and MIL-M-87268 is under preparation by the DOD-established Tri-Service IETM Working Group. This Specification or Handbook is scheduled for completion in the third quarter of FY 1994.

6.2.1 Recommendation for Navy Use

The Navy should continue to assess the effectiveness of available commercial Portable Electronic Display Devices. An in-house Navy development does not appear to be needed. Industry should be encouraged to develop rugged, capable PEDDs and associated operating and presentation software capable of operating on a wide range of suitable devices. The present processing and display requirements for a shipboard or flightline PMA/PEDD do not seem beyond the current industrial state of the art, and with the addition of environmental capabilities (e.g., temperature extremes, ruggedness, salt, and EMI), Commercial-Off-The-Shelf (COTS) devices should provide adequate basic systems for Navy PMA use. Existing COTS software for such devices is generally considered unsatisfactory and would require rework or complete development in many particulars.

6.3 IMPROVEMENT OF GRAPHICS PRESENTATION

Work should be undertaken to provide needed improvements in graphics displays (designed for bench-mounted Electronic Display Devices and for PMAs) and in the graphics themselves (e.g., elimination of stairstepping), in the speed of handling graphics (e.g., providing the "next" screen in less than one second), and in comprehensible presentation of the type of information which is usually provided to technicians on large-scale <u>paper</u> drawings. As shown by this Test, currently expressed requirements for scrolling are difficult to implement satisfactorily, and should be eliminated if effective alternative display techniques can be found.

6.4 ASSESSMENT OF REDUCTION IN TRAINING REQUIREMENTS WITH IETM USE

This Test (and others) have shown the effectiveness of highly proceduralized fault-isolation and corrective-maintenance procedures in significantly improving performance of inexperienced technicians. Instruction required for use of an IETM/PMA combination itself is minimal. The interaction between the need for schoolhouse and on-board training and the use of IETMs should be carefully assessed with an eye to significant reduction in formal training requirements, and to define the level to which training information should be incorporated into the IETM itself.

6.5 INTERACTION OF IETMs WITH OTHER MAINTENANCE-RELATED FUNCTIONS

An IETM/PMA combination has been shown to be most effective in streamlining accomplishment of interactive functions involving maintenance and other logistics processes (e.g., parts ordering and maintenance reporting). It is recommended that effort be carried out or increased to define the extent to which other maintenance and maintenance-related functions should be integrated with IETMs (in addition to those which were demonstrated in this Test). The achievement of complete Technical Information integration throughout the entire maintenance process, and provision of automated interfacing with associated management systems such as NALCOMIS, offer great promise of increased efficiency (in terms of reduced time and costs) all along the logistics chain. Such an integration of all logistics-support Technical Information is the basis of IMIS as well as of the Navy AMIDD (Aircraft Maintenance Integrated Diagnostics Demonstration) concept.

6.6 IMPROVEMENT IN BITE COUPLING WITH PMA

Based on effective interaction between the PMA and on-aircraft BITE through use of the 1553 bus, as demonstrated in this Test, future on-aircraft BITE installations, design of DSUs for future aircraft (and for other weapon systems), and other test-equipment considerations should take into account the possibility of direct coupling to, and interactive information exchange with, a PMA or other IETM display system. Mechanisms for such coupling (e.g., cables, plugs) need work to minimize interference with other procedures or cumbersome arrangements.

6.7 REVIEW OF DYNAMIC DIAGNOSTICS

The concept of "dynamic diagnostics" (i.e., automated Artificial-Intelligence type application of information accumulated in the Display Device itself during the maintenance history of a weapon system, used to improve Fault-Isolation procedures on a case-by-case basis) needs additional development effort and laboratory testing prior to further field testing. Also, guidance should be prepared to provide Contractors with trade-off considerations to permit choices between TI prepared under full control of a human author and TI fully automated by Delivery Device algorithms based on direct interaction with the IETMDB.

6.8 CONTINUED IMPROVEMENT IN ELECTRONIC DISPLAY OF TI

It is clear from this Test (and from previous operational tests) that further work needs to be done on optimization of the display of Technical Information on luminous screens of all types. This effort should be based on work done to improve graphics (see section 6.3) and on work done to improve PMA display capability (see section 6.2), but will also require further Human Factors effort of the type described in ref. 11. Results of such efforts should be standardized and incorporated into MIL-M-87268.

REFERENCES

1. Military Specification ***MIL-D-87269: Data Base, Revisable: Interactive Electronic Technical Manuals, For the Support of.*** 20 November 1992. (Prepared by the Tri-Service Working Group for Interactive Electronic Technical Manuals.)

2. Military Specification ***MIL-M-87268: Manuals, Interactive Electronic Technical; General Content, Style, Format, and User-Interaction Requirements.*** 20 November 1992. (Prepared by The Tri-Service Working Group for Interactive Electronic Technical Manuals.)

3. Thomas, D.L.; and J.D. Clay. ***Computer-Based Maintenance Aids for Technicians, Project Final Report.*** AFHRL-TR-44, Wright Patterson AFB, OH; Air Force Human Resources Laboratory, Logistics and Human Factors Division. August 1988.

4. Fuller, Joseph J.; Theodore J. Post; and Anne S. Mavor. ***Test and Evaluation of the Navy Technical Information Presentation System (NTIPS), F-14A Field Test Results.*** DTRC-88-036. September 1988.

5. Nugent, W.A.; S.I. Sander; D.M. Johnson; and R.J. Smillie. ***Troubleshooting performance using paper and electronic documentation (NPRDC TN 87-41).*** Navy Personnel and Research and Development Center, San Diego, CA. December 1987.

6. Fuller, Joseph J.; Raymond L. LeBeau; Anne S. Mavor; Theodore J. Post; and Charles S. Sawyer. ***Test and Evaluation of The Navy Technical Information Presentation System (NTIPS), AN/SPA-25D Test Results.*** DTRC-88-035, September 1988.

7. Wisher, R.A.; and J.P. Kincaid. ***Personal Electronic Aid for Maintenance: Final summary report (ARI Research Report 1516).*** U.S. Army Institute for the Behavioral and Social Sciences, Alexandria, VA. March 1989.

8. Link, William R., CAPT, USAF; Janet E. Murphy, 2LT, USAF; Eric N. Carlson, 2LT, USAF; Donald L. Thomas; James Brown; and Reid Joyce. ***Integrated Maintenance Information System, Diagnostic Demonstration.*** AFHRL-TR-90-41, AFHRL Logistics and Human Factors Division, WPAFB. Aug 1990.

9. Link, William R., 2LT USAF; Joseph C. Von Holle, CAPT USAF; Dwayne Mason, 2LT USAF. ***Integrated Maintenance Information System (IMIS): A Maintenance Information Delivery Concept.*** AFHRL-TP-87-27. November 1987.

10. Cook, Garth; Johnnie Jernigan; Nicola Maiorana; Chuck Schmidt; Mike Costarella; and Eric N. Carlson, 1LT USAF. ***Enhancing the Integrated Maintenance Information System Diagnostic Model (IMIS-DM): Version 5.0.*** USAF Armstrong Laboratory, Air Force Systems Command, Brooks AFB, Texas. AL-TR-1991-6681. February 1992.

11. Wampler, Jeffrey L. ***Baseline IMIS Human Computer Interface Specification (HCIS).*** AL/HRGO. 9 March 1992.

12. Rainey, Samuel C.; and Joseph J. Fuller. ***The Interactive Electronic Technical Manual: Requirements, Current Status, and Implementation-Strategy Considerations.*** DTRC-91/016. July 1991.

13. Bavani, S.; and K. Tune. ***Naval Air Test Center, Project Test Plan, Navy/Air Force F/A-18 Test of an Interactive Electronic Technical Manual (NATC per NATC Instruction 3960.10C, Change 2, 7 October 1982).*** Naval Air Test Center, Strike Aircraft Test Directorate, Reliability and Maintainability, Patuxent River Naval Air Station, MD. April 1991.

14. Bavani, S.; and K. Tune. ***F/A-18 Integrated Flight Control System Aircraft Level Fault Insertion Test (NATC SA-66R-88).*** Strike Aircraft Test Directorate, Naval Air Test Center, Patuxent River Naval Air Station, MD. February 1989.

15. Post, Theodore J.; Robert J. Smillie; L. John Junod; Karen June; and Gail McCarty. ***Plan for the Navy/Air Force F/A-18 Test of the Interactive Electronic Technical Manual.*** DTRC/TM-12-91/10. May 1991.

16. Military Specification ***MIL-Q-87270: Quality Assurance Program: Interactive Electronic Technical Manuals and Associated Technical Information; Requirements for.*** 20 November 1992. (Prepared by The Tri-Service Working Group for Interactive Electronic Technical Manuals.)

ABBREVIATIONS AND ACRONYMS

1553	Aircraft Maintenance Data Bus Standard 1553 on USAF F-16, and Navy/USMC F/A-18 Aircraft
3M	Maintenance and Material Management
AF	Air Force
AL/HRGO	Armstrong Laboratory/Air Force Human Resources Directorate, Wright-Patterson Air Force Base, Dayton, Ohio
AMIDD	Aircraft Maintenance Integrated Diagnostics Demonstration
ARI	Army Research Institute
ATE	Automated Test Equipment
BIT	Built-in Test
BITE	Built-in Test Equipment
BLIN	BIT Logic Inspection (number)
CALS	Computer-aided Acquisition and Logistics Support
CDI	Collateral Duty Inspector
CDM	Content Data Model: Basis of IETMDB
CDNSWC	Carderock Division, Naval Surface Warfare Center, Bethesda, MD
CGM	Computer Graphics Metafile
CMAS	Computer-based Maintenance Aids System: Predecessor of the PMA of this Test
CND	Can Not Duplicate
COTS	Commercial-Off-The-Shelf (product)
DDI	Digital Display Indicator

Abbreviations and Acronyms, cont'd

DM	Diagnostic Module
DSU	Data Storage Unit
EDS	Electronic Display System
FCC	F/A-18 Flight Control Computer
FCCA	FCC "A"
FCCB	FCC "B"
FCS	F/A-18 Flight Control System
FRM	Fault Reporting Manual
GCSFUI	*General Content, Style, Format and User Interaction Requirements* Specification (now issued as *MIL-M-87268*, dated 20 Nov 1992)
GSE	Ground Support Equipment
HCIS	Human Computer Interface Specification (See ref. 1.)
HF	Human Factors
IBIT	Initiated Built-in Test
IETM	Interactive Electronic Technical Manual
IETMDB	Interactive Electronic Technical Manual Data Base (Specification now issued as *MIL-D-87269*, dated 20 Nov 1992)
IMIS	Integrated Maintenance Information System
MCAIR	McDonnell Douglas Aircraft Company
MBIT	Maintenance Built-in Test
MC	Maintenance Control
MDAS	Maintenance and Diagnostic Aiding System

Abbreviations and Acronyms, cont'd

MIPS	Million Instructions Per Second
MOS 6337	USMC Military Occupational Specialty - Electrician
MOS 6317	USMC Military Occupational Specialty - Communication/Navigation/Radar
MSP	Maintenance Status Panel
MTBF	Mean Time Between Failures
MCAS	Marine Corps Air Station
NALCOMIS	Naval Logistics Command Management Information System
NCC&OSC	Naval Command Control and Ocean Surveillance Center, San Diego, CA
NPRDC	Navy Personnel Research and Development Center
NTIPS	Navy Technical Information Presentation System
NSWC	Naval Surface Warfare Center
PBIT	Periodic Built-in Test
PEAM	Personal Electronic Aid for Maintenance
PEB	Pre-Expanded Bin
PEDD	Portable Electronic Delivery Device (a Navy term equivalent to PMA)
PCMAS	Portable Computer-based Maintenance Aid System
PMA	Portable Maintenance Aid (IMIS term equivalent to PEDD)
PS	Presentation System
R&D	Research and Development
R&M	Reliability and Maintainability
RMTS	Rudder Manual Trim System

Abbreviations and Acronyms, cont'd

R&R	Remove and Replace
RTOK	Retest OK
SATD	Strike Aircraft Test Directorate, Patuxent River Naval Air Station
SEI	Systems Exploration, Incorporated
SGML	Standard Generalized Markup Language
SMA	Scientific Management Associates, Inc.
SME	Subject Matter Expert
SRL	Systems Research Laboratory
T&E	Test and Evaluation
TI	Technical Information (Paper-based or Electronic)
TIDER	Technical Information Deficiency and Evaluation Report
TG	Test Group (procedure)
VIDS/MAF	Visual Information Display System/Maintenance Action Form (NAVAIR maintenance-control and reporting form)
WC	Work Center
WP	Work Package
WRA	Weapon Replaceable Assembly

APPENDIX A

A Detailed Presentation

of

Technicians' Debriefing Comments on the IETM

THIS PAGE 96 INTENTIONALLY LEFT BLANK

for reverse of APPENDIX A title page.

INTRODUCTION

Technicians' opinions concerning the IETM/PMA combination were solicited at the following stages of the Test:

- After each of their six troubleshooting performances.
- As part of the Questionnaire, they were asked to complete after all fault exercises.
- During a Structured Interview following completion of all fault exercises.

Subject Technicians were encouraged to identify the positive features of the IETM/PMA and to provide any suggestions for improvement. The two subsections below summarize the opinions reported by the Technicians; first, with respect to IETM features which they thought effective and beneficial and, second, with respect to the features which they believed needed improved.

1. **Effective Features of the IETM/PMA**

   a. Integration of Information. Typical of the several comments on this feature was: "Everything you need is right there; you don't have to page through a bunch of books". The consolidation the Technicians were referring to includes the side by side presentation of text and supporting graphics, the linking of cross reference or branching procedures and the ability to call locator graphics, which are accessed via Required Conditions or a soft key. One negative aspect of this feature concerned allocation by authors of PMA instructions for locators among the three access techniques; e.g., some Technicians thought that too many locators had been made an integral part of the text-graphic instructions, which slowed their performance.

   b. Automated Functions. Technicians were enthusiastic about the automation of what had been manual and sometimes error -prone tasks. The automated versions of the tasks consisted of:

      (1) VIDS/MAF completion (especially the Parts-Ordering section).

      (2) Memory Inspect.

      (3) Control of the FCS BIT via the 1553 multiplex bus.

   c. Error Prevention/Reduction. This IETM/PMA benefit was identified by Technicians during debriefings and quantified by the data collected during the test. An example of the types of

errors which are preventable by IETMs but allowed by paper TMs is the back-and-forth method of doing maintenance in accordance with any information source. When using paper TMs, the open book usually shows facing pages. After completing a step at the aircraft, the technician returns to the book to regain his place in the instructional sequence. Occasionally, the technician resumes the instructional sequence at a wrong place (for example, on the right-hand page instead of left-hand page; or by dropping a row when moving to the right to get the "Go To" instruction). Technicians in this test committed both error types leading to failures to solve the problem.

d. PMA Portability. Technicians pointed out that the PMA's relative portability constituted an advantage as compared to the numerous paper TMs they were required to carry to provide an equivalent amount of information. In addition, Technicians assessed the PMA's size and weight as acceptable.

e. Selection of Information for Display. Technicians approved of the PMA's capability to select for display only that information relevant to the Technician's assigned aircraft; e.g., the Technician no longer needed to review the paper TM's blocks of tail numbers to find the block and the associated procedure which applies to his aircraft. This IETM capability eliminates what has been an error-prone task. Using the paper TM, more than one Technician followed a wrong set of procedures through making the wrong "Effectivity" choice.

2. Suggestions for Further Improving the IETM

One of the Structured Interview questions asked Technicians to note other maintenance or maintenance-related functions that might be supported by applying the IETM automation approach. Although the services are already pursuing many of the suggested capabilities, they are reported here as a field endorsement of such programs. The following is a summary of the Technicians' suggestions.

a. Link to Maintenance Control (MC). The purpose of the link would be to provide MC with real time job status information. In fact, a much broader link is under development; i.e., dump of the DSU, pilot/crew debriefing.

b. Next Day's Flight Schedule. One Technician suggested that incorporation of upcoming flight schedules by Maintenance Shops would allow Technicians to target their efforts more effectively, e.g., concentrate on the mission equipment needed to support the schedule.

c. PMA/DSU Interface. This suggestion is directed at obtaining directly from the DSU maintenance-relevant information which is not now available to the Technicians: e.g., deeper Fault Isolation (to a component within a Weapons Replaceable Assembly (WRA) as compared

with one or more WRAs), and flight conditions which prevailed at fault detection. This feature is also under active development.

d. Adding Training Content to the IETM. The Technician making this suggestion perceived the IETM as having the potential to support On-the-Job-Training for new squadron personnel. This capability is also under development by the Services.

e. Work Planning. Some of the Technicians reported that their normal troubleshooting starts with a planning session to "scope" out the problem, and they believed that the P inhibited this phase of their work. They suggested that a browse mode might be included in the PMA to facilitate this process. They believe, also, that the troubleshooting diagrams (the coded block diagrams) and the schematics have potential to meet this need.

f. PMA's Response Time. The elapsed time between pressing "NEXT" and the appearance of follow-on screen was deemed too long by some Technicians, especially when a complex graphic was part of the follow-on screen. In some instances, the response time approached 10 seconds. One senior Technician complained that this was especially frustrating when after the graphic of the follow-on screen appeared, he found he didn't need it. He would have preferred a "checklist-type" presentation; e.g., brief textual statements of steps with supporting graphics available via a soft function key. (This objection has been repeatedly made in IETM field tests. Graphics presentation software is still unsatisfactory in this regard. Emphasis must be added to efforts to improve this capability.)

g. Pre-Expended Parts. As already noted, the automated Parts-Ordering process received strong support from the Technicians; all used it and all endorsed it. However, the process, as included in the PMA for this test, did not allow the Technicians to follow their normal practice of checking a local Pre Extended Bin (PEB) for smaller parts, as compared to completing the more time-consuming, formal ordering process. This situation occurred in the two Relay Tests; relays are parts sometimes included in the PEB. Technicians commenting on this aspect of the PMA suggested that including a PEB feature would be an additional benefit.

h. Additional Locator Information on Wiring Diagrams. The IETMs used a novel type of wiring diagram whose overall circuitry is limited to that which occurs between two components of interest, and whose circuitry detail was far less than conventional schematics. The reaction to these diagrams was mostly favorable but one consistent request was that locator information be included between end points of the diagram, i.e., add locations of doors, bulkheads and panels between the end points. The rationale for this request was that the additional information would allow Technicians to save time by using the half-split technique. In addition, a request was made to include test-tolerance information where appropriate.

i. Abbreviated Wiring Diagrams vs Schematics. Technicians' reaction to the abbreviated wiring diagrams was mixed, some considering that the detail was adequate, others that the detail was not sufficient. The latter Technicians believed that the abbreviated wiring diagrams were adequate for the faults used during the test, but that they would be inadequate for more complex faults. In addition, they believed that full schematics would provide them with an overview of the scope of the fault, information not available elsewhere in the IETM. They believed that without schematic information, they had little basis for following the logic of the IETM's procedural sequence. In essence, they were asking: How can technicians assess "Recommended Tests" and "Ranked Actions" if they have no means for understanding the weapon system's hardware? They believed that some way needs to be found to present fuller schematics on small screens. Techniques suggested for accomplishing this included "select a section and zoom" and "scrolling".

j. Level of Detail. Comments both pro and con were offered on the explicitness of the IETM instructions. Some respondents believed that gearing the instructional explicitness to the novice was a good feature that would cut down on human error; others believed it was too detailed and slowed the performance of the more experienced Technicians. These comments suggest that a need exists for further research on balancing the "Expert - Novice" presentations of the two track system.

k. Inadvertent Key Activation. Use of the PMA in performing the six Fault-Isolation tests involved considerable movement of the PMA; e.g., to the aircraft, from the ground to the cockpit, and back. Technicians observed that during these moves it was easy to press a key inadvertently, resulting in a new and unwanted screen. One Technician suggested the inclusion of a lockout key to prevent these disruptive occurrences.

l. Screen Glare. Technicians commented that even at angles of view near 90°, it was occasionally difficult to make out screen content because of glare. These same Technicians were quick to point out that the backlit feature was a great countermeasure for this problem, yet they realized that this design feature involves a trade-off because of the extra power needed for the backlit mode.

m. PMA Awkward in Cockpit. Much of the troubleshooting work is performed in the cockpit and some portion of this involves movement of the flight-control stick. Technicians complained that the PMA is an impediment to the stick movement.

n. 1553 Bus Interface. The overall opinion as to the 1553 link to the aircraft was positive, but improvement was requested for several aspects.

(1) The hookup required disabling the mission computers which in turn disabled the Digital Display Indicators (DDIs). This criticism stated that the computers are needed to collect Engine Life data, and Technicians preferred to have the DDIs active. NOTE: Taking the DDIs and computers off-line was an expediency for the test and would not be done for operational use.

(2) The Nosewheel Well location of the interface plug precludes any maintenance action that requires opening and closing of the Nosewheel doors.

(3) The 1553 umbilical cord deterred PMA portability.

(4) The feed from the data bus to the PMA was presented on two screens which had to be compared. However, the screens to be compared were not adjacent to each other, making the comparison more difficult than necessary.

o. Watch Icons. It was observed that a standard location and a more attention-getting appearance are desirable for the Watch icon (the icon indicating that the computer was working).

p. Cursor Expectancies. A complaint was made that the cursor movement violated expectations, e.g., a press of the right arrow key did not always result in a movement to the right.

q. Series of Checks. The F/A-18 troubleshooting procedures include many instances in which a series of checks must be made; e.g., a set of continuity checks. In the IETM treatment, when the Technician entered his first No Go, the device branched to the next step (rather than completing the remainder of the checks). This procedure was considered undesirable because, after resolving the fault related to the first No Go, the System Health check might fail and lead back to the incomplete series. The commenting Technician believed that the IETM ought to allow completion of the set of checks.

r. Limited Access to Important Information. Technicians complained that some important information, notably Initial Set Up and Fault Verification, was available only via the VIDS/MAF (Part I), and further, it was not possible to backtrack into the VIDS/MAF from a downstream position.

s. Cursor Control. The PMA offered both a thumb knob and the arrow keys as means of controlling the cursor. The Technicians favored the arrow keys over the thumb knob. No reasons were given.

t. Number Keys. Technicians favored the number sequence 1 to 0 over the 0 to 9 sequence.

u. Operational Realism. The Ground-Support Equipment (GSE)-intensive configuration of the Test setup was criticized as being in conflict with the operational practice of using the aircraft's hydraulic pressure rather than the external hydraulic generators used in the test. The criticism is legitimate, but the external hydraulic generators were a test expedient and not intended as an operational measure. Other comments about the lack of realism in the PMA included the way in which VIDS/MAFs were prepared for the multiple faults ("Maintenance Control doesn't do them that way").

v. Unfriendly Abort and Restart. One Technician noted that the PMA does not offer a user-friendly way to abort and restart a process such as a test sequence.

w. Collateral Duty Inspector (CDI) Sign Off. A Technician suggested that IETM should not advance to the next segment of the procedure until the Collateral Duty Inspector signs off at designated point(s).

x. Confusing Similarities among Required Conditions, Follow-On, and Closing Actions. The confusion among these IETM presentations was based on their visual similarity and the appearance of repetition. As an example, Technicians complained that they were being directed to reconnect plugs only to find that a later screen called for disconnecting the same plug. These procedures should be reviewed for possible consolidation.

y. Diagnostic Block Diagram. Comments on these diagrams were positive (e.g., they narrowed down the possibilities, showed the interrelationships) but contained some negative impressions (e.g., marginally acceptable, somewhat confusing, good but mainly applicable to more complex problems, did not contribute over and above troubleshooting instructions). This mixed review indicates a need to define more precise uses for this capability; e.g., redo the diagnostic-block diagrams to serve as an overview of the fault, a need Technicians were not able to meet by using existing IETM content.

z. Fragility of the PMA. The need to treat the PMA gently was identified as a characteristic which needs design attention. PMA ruggedization is an established requirement for which draft Military Specifications have been established and appropriate development efforts are underway.

aa. Capability to Withstand Harsh Environmental Conditions. Saudi Arabia and Somalia were mentioned as typical operating environments for the USMC, and of course the PMA would have to be able to function under environmental conditions encountered in those countries. Such environmental requirements are well known and PMA-design improvements are under development.

ab. Better Labelling of Soft Function Keys. The specific complaints were not stated but a review of the key labels would be profitable.

ac. Battery Life and Recharge. The operating life of newer batteries is considerably better than the batteries used in the test. However, the life and recharge constraint is a limitation and is being worked on.

ad. Alert Cue for Long Series. The IETM presents long series of tests (e.g., Left Stab Intermittent Wiring tests) on three or more screens. The technician can waste time by reading the first instruction, going to the aircraft to carry out the test, returning to the PMA to enter the result and then, upon advancing to the next screen, finding that he has to return to the previous test location. The technician suggested including a prompt at the outset of these series to minimize any such back-and-forth time, e.g., look ahead and jot down the pin numbers, or carry the PMA with him if location of tests is within the cord radius.

ae. Time Spent So Far Against Normal Fractional or Total Time. One technician suggested that the PMA present some means of showing average task-completion time, with a running indication of how far into this average time the work had progressed (e.g., a bar chart showing 25%, 50%, 75%, 100%).

af. Clarification of the Highlight and Select Functions. In a typical use of these PMA keys, a technician would move the cursor over the desired item (this action highlights the item), then press the SELECT key and finally press a key to implement the pertinent action. Apparently, other PMA sequences (or other computer experiences) led technicians erroneously to believe that pressing only NEXT after highlighting an item implemented that item's action. This confusion led to wasted time, some unexpected screen advances and occasionally an erroneous input to the PMA. For example, in a list of test-result options with one defaulted, the technician moves cursor over a non default value, resulting in its being highlighted. He then presses NEXT intending this action to enter the highlighted item into the PMA. In fact, without first pressing SELECT, pressing NEXT will enter the default item (instead of the highlighted item) into the PMA. The faulty sequence results in serious deviations from the desired diagnostic path.

ag. Less-Than-Full-Use of Function Keys. Certain PMA screens offer the technician more than one way to interact with or manipulate the screen: hard keys, highlight and select, soft key, NEXT to a default. Most technicians appeared to learn and then go with one technique over the alternatives even though it might have been more efficient and user friendly to use techniques best suited to the situation at hand, e.g., NEXT for defaulted option; soft key for choosing special options.

THIS PAGE 104 INTENTIONALLY LEFT BLANK SO THAT APPENDIX B BEGINS ON AN ODD-NUMBERED PAGE.

APPENDIX B

BIOGRAPHIC DATA SHEET

THIS PAGE 106 INTENTIONALLY LEFT BLANK

for reverse of APPENDIX B title page.

BIOGRAPHIC DATA SHEET

Name:______________________________ Participant #:________

Rank/Rate/Job Title:__________________ NEC:______________

Time in Service: ____________ Time in NEC: ______________

Command/Activity Name & Location: _________________________

Dept. Title/Code: ____

Are you right-handed? _________ Yes __________ No

Years/Months at this Command/Activity: ______________________

Navy Schools Attended (Provide dates):

______________________________ ________________________

______________________________ ________________________

F/A-18 Maintenance Experience (Years/Months): ______________

Note: *List specific F/A-18 systems/subsystems you have experience on, i.e. the flight control system.*

Specify percentages:
Hands-on:_______ Instructor:_______ Other (Specify):______

Other Aircraft Maintenance Experience (Specify): ______________

____

____

Do you have any computer programming training experience? (Please specify, e.g., octal, binary, digital fundamentals, etc.), e.g., Course taken, language, familiarity, etc.

____

____

Please summarize the computer type and applications you are familiar with: ______________________________________

____

____

THIS PAGE 108 INTENTIONALLY LEFT BLANK

for reverse of Biographic Data Sheet.

APPENDIX C

PERFORMANCE OBSERVATION FORM

THIS PAGE 110 INTENTIONALLY LEFT BLANK

for reverse of APPENDIX C title page.

Participant #:______

PERFORMANCE OBSERVATION FORM

Problem #	Presentation Method		Date of Test	Initials of Observer(s)
	PMA	Manual		

SECTION 1: PRELIMINARY ACTIVITIES

Note: Entries to this section should be made immediately after the VIDS/MAF is first presented to the test participant.

1. START TIME: ____________

2. After obtaining the VIS/MAF, list any problems (e.g., finding the technical manuals,etc.) you detect in gathering the technical information and tool kit prior to exiting the work center. Please note any problems in accessing the VIDS/MAF via the PMA, e.g., does the technician make (or appear to make) inappropriate button presses on the PMA.

____

____

3. How much time did the technician spend reviewing the technical information?

   ________START ________STOP ________NONE

4. STOP TIME: ____________

SECTION 2: SET-UP AT AIRCRAFT

1. START TIME ____________

2. Describe set-up problems for placing PMA or WP at the aircraft. [For PMA, include connection to the 1553 bus.]

____

____

3. Note any problem "verifying" electrical and hydraulic hook-ups.

____

____

4. Detail steps technician took to verify fault symptoms documented on VIDS/MAF prior to initiating troubleshooting, i.e., describe the process for initiating the BIT (PMA should be straight forward with the PMA controls; WP will require knowledge or technical information referencing to run the appropriate BIT).

____

____

5. STOP TIME: ____________

Participant #:______

SECTION 3: TROUBLESHOOTING ACTIVITIES

> Note: Entries to this section should be made immediately after the fault symptoms have been verified through the appropriate BIT.

1. START TIME: ____________

2. In the spaces below, list and briefly describe all *fault detection and isolation tests* in the order each was performed; and, note whether the test was valid or invalid. Include applicable technical information consulted for each test performed; then briefly describe the results of each test under the heading: "Test Outcome." Continue on additional sheets as necessary.

Step No.	Description of Fault Detection/ Isolation Action(s) Performed Note whether it was a valid or invalid test	Tech. Info. Checked Vol/Section	Test Outcome

Participant #:______

SECTION 3: CONTINUATION SHEET

Step No	Description of Fault Detection/ Isolation Action(s) Performed Note whether it was a valid or invalid test	Tech. Info. Checked Vol/Section	Test Outcome

3. List each time the technician concludes that he/she has found the failed component; and, the outcome, i.e., success or failure.

____

____

4. STOP TIME: __________

Participant #: ______

SECTION 4: REMOVE AND REPLACE

1. START TIME: ____________

2. Describe any problems the technician has with accessing the correct "Remove and Replace" procedure.

____

____

5. STOP TIME: ____________

SECTION 5: REPLACEMENT PARTS IDENTIFICATION & REQUISITIONING

> Note: Entries to this section should be made immediately after the test participant has isolated the FCS malfunction to the faulty weapons replaceable assembly (WRA).

1. START TIME: ____________

2 After identifying the correct "Remove and Replace" procedure, detail all the steps the technician takes to access parts information and identify the faulty WRA. Note all problems.

____

____

3 Note that all entries to the supply requisition (i.e., for ordering a replacement WRA) are complete and correct. Note all problems.

____

____

4. STOP TIME: ____________

Participant #:______

SECTION 6: REQUISITIONING PROCEDURES

1. START TIME: ____________

2. After requisitioning the part, detail all the steps the technician takes to complete the required paper work. Note all problems.

____

____

3. STOP TIME ____________

SECTION 7: INSTALLATION AND CHECKOUT

1. START TIME: ____________

2. Although simulated, the technician will be "given" the replacement part and asked to "install" it. Describe any problems the technician has in accesssing the correct "Remove and Replace" procedure.

____

____

____

____

3. After the "new" component has been installed, detail the verification process the technican follows to ensure the aircraft is operational.

____

____

____

____

4. STOP TIME: ____________

Participant #: ____

SECTION 8: VIDS/MAF COMPLETION

Note: Entries to this section should be made immediately after the test participant has received instructions from the test administrator to fill out the VIDS/MAF for the troubleshooting problem just completed. It is anticipated that this activity will be performed in the F/A-18 work center.

1. START TIME: ____________

2. Was correct technical information accessed and used when completing entries to the VIDS/MAF?

   ____ YES ____ NO.

If "NO," list discrepancies obse n the spaces below:

____

____

____

____

3. Were all applicable data entries to the VIDS/MAF complete and correct? ____ YES ____ NO.

If "NO," list discrepancies observed in the spaces below:

____

____

____

____

4. STOP TIME: ____________

APPENDIX D

USER EVALUATION QUESTIONNAIRE

THIS PAGE 118 INTENTIONALLY LEFT BLANK

for reverse of APPENDIX D title page.

Participant #:____

USER EVALUATION QUESTIONNAIRE

Introduction

The Portable Maintenance Aid (PMA) that you used during the F/A-18 test is an example of how maintenance procedures and technical data may be delivered for next generation aircraft. Since you and other technicians may be using such a device in the future, your feedback on the current model of PMA is essential. Accordingly, this questionnaire was designed to obtain your opinions about the design, operation, and usefulness of PMA.

Specifically, we ask you to evaluate the questionnaire items using the 5-point scale appearing to the right of the items. Rate each item by placing an "X" in the appropriate column. We encourage you to respond to as many of the questionnaire items as possible but recognize that there may be some items you cannot evaluate based on your limited experience with PMA. In those cases, place an "X" in the column headed: "Can't Evaluate".

Section 1: Physical Features of PMA

	Scale Values					
Items	Unsatis-factory	Marginal	Satisfactory	Highly Satisfactory	Outstanding	Can't Evaluate
1. Overall weight of the device.						
2. Overall size (width and length) of the device.						
3. Overall height (thickness) of the device.						
4. Ease of positioning/repositioning PMA at the worksite.						
5. Ease of connecting PMA to the 1553 bus.						
6. Size of keys.						
7. Location of keys.						
8. Spacing of keys.						

Section 1: Physical Features of PMA (cont.)

Items	Unsatis-factory	Marginal	Satisfactory	Highly Satisfactory	Outstanding	Can't Evaluate
9. Response time after key press.			✓			
10. Appropriateness of function keys.				✓		
11. Adequacy of screen size for displaying information.					✓	
12. Brightness of screen.					✓	
13. Contrast between letters/graphics and background.					✓	
14. Amount of glare on display screen.						
15. Key pressure resistence/sensitivity.					✓	

Section 2: Software/Operational Features of PMA

Items	Unsatis-factory	Marginal	Satisfactory	Highly Satisfactory	Outstanding	Can't Evaluate
16. Spacing of information on the screen (vs. crowding).					✓	
17. Legibility of displayed letters, numbers, and words.					✓	
18. Adequacy of organization/arrangement of information.					✓	
19. Adequacy of options on menus/function keys.					✓	
20. Adequacy of menu organization.					✓	
21. Ease of using menus/function keys.					✓	

Section 2: Software/Operation Features of PMA (cont.)

Items	Scale Values					
	Unsatis-factory	Marginal	Satisfactory	Highly Satisfactory	Outstanding	Can't Evaluate
22. Ease of moving cursor with arrow keys.					✓	
23. Ease of moving cursor by pressing number keys.					✓	
24. Ease of moving cursor with thumb knob.					✓	
25. Ease of returning to appropriate place in a set of procedures after branching elsewhere in data base.						✓
26. Adequacy of information for supporting maintenance tasks (i.e., completeness, accuracy, relevance).					✓	
27. Appropriate number of procedural steps per screen.					✓	
28. Adequacy of PMA for completing supply requisitions, VIDS/MAFs, etc.					✓	

Section 2: Software/Operational Features of PMA cont.)

Items	Unsatis-factory	Marginal	Satisfactory	Highly Satisfactory	Outstanding	Can't Evaluate
	Scale Values					
29. Scrolling function availability.						✓
30. Scroll mode (hard key).						✓
31. Scrolling with arrow keys and SELECT key.						✓
32. Availability of functions on soft keys.				✓		
33. Menu item names.					✓	
34. Availability of menu functions.					✓	
35. Cursor visibility.					✓	
36. Legibility of graphics.					✓	
37. Adequacy of detail on graphics.					✓	
38. Ease of accessing Locator diagrams.					✓	
39. Adequacy of detail provided on Locator diagrams.					✓	
40. Adequacy of wiring diagrams.					✓	

Section 3: Comparative Assessment

This section of the questionnaire deals with the efficiency and effectiveness of PMA compared to existing technical manuals for the F/A-18 aircraft. Note that the words listed under the heading scale values have changed. Please review this scale carefully before rating the items in this section. To avoid repetition in the wording of the items contained in this section, begin each with the phrase:

The PMA can be compared to F/A-18 technical manual Work Packages (WP) in the following ways ...

Items	Scale Values					
	WP Significantly Better	WP Slightly Better	No Difference	PMA Slightly Better	PMA Significantly Better	Can't Evaluate
41. The overall time and effort required to obtain maintenance information.				✓		
42. The fatigue you experienced when using it.					✓	
43. The confusion or frustration you experienced in obtaining needed technical information.					✓	
44. The overall organization and arrangement of technical information.				✓		
45 Obtaining access to needed technical information.				✓		
46. The method of presenting technical information.					✓	
47. The overall completeness, accuracy, and applicability of technical information.					✓	
48. Supporting maintenance on the F/A-18 flight control system.				✓		

Section 4: General Reactions and Comments

The spaces below are provided for making any comments, complaints, suggestions, etc. you may have regarding the current model of the PMA device (e.g., for any item rated "unsatisfactory" or "Marginal", it would be helpful to know why it received that rating). Comments may be continued on the reverse side of this page if necessary.

This concludes the user evaluation questionnaire. Your assistance in providing this essential information is appreciated.

APPENDIX E

STRUCTURED INTERVIEW GUIDE

THIS PAGE 126 INTENTIONALLY LEFT BLANK

for reverse of APPENDIX E title page.

Participant #: ______

STRUCTURED INTERVIEW GUIDE

What we will be talking about is based upon the degree that you used the following PMA features:

- Scrolling, panning, zooming
- Circuit schematic and wiring diagrams
- Switching between levels of detail
- On-line HELP
- Cross-references to related procedural steps/technical information
- Electronic form filling (e.g., for supply requistions, VIDS/MAF, etc.)

I. Specific questions for PMA users:

1. Did you use scrolling, panning, or zooming? If YES, then:

a. Were these features useful?
b. On a scale of 1 to 5 with 1 being very easy, and 5 being very difficult, how easy were these features to use?

1	2	3	4	5
[]	[]	[]	[]	[]
Very Easy				Very Difficult

c. Can you add to that or give an example?

____

____

____

____

2. Did you use circuit schematic or wiring diagrams? If YES, then:

a. Was enough context provided on the diagrams to prevent you from getting "lost"?
b. On a scale of 1 to 5 with 1 being very easy, and 5 being very difficult, how easy were schematic and wiring diagrams to use?

1	2	3	4	5
[]	[]	[]	[]	[]
Very Easy				Very Difficult

c. Can you add to that or give an example?

____

____

____

____

3. Did you use more than one level of detail? If YES, then:

a. Which level of detail was most useful to you? Why?

b. On a scale of 1 to 5 with 1 being very useful, and 5 being not useful at all how useful were the two levels of detail?

1	2	3	4	5
[]	[]	[]	[]	[]
Very Useful			Not Useful At All	

c. Are two levels enough? If not, how many levels of detail should be provided?

____

____

____

____

4. Did you use on-line HELP? If YES, then:

a. Did on-line HELP provide useful information?

b. On a scale of 1 to 5 with 1 being very easy, and 5 being very difficult, how easy was on-line HELP to use?

1	2	3	4	5
[]	[]	[]	[]	[]
Very Easy			Very Difficult	

c. Can you add to that or give an example?

____

____

____

____

5. Did you make cross-references to other procedural steps/technical information in the database? If YES, then:

a. Was the cross-referenced information useful/relevant to the task at hand?

b. On a scale of 1 to 5 with 1 being very easy, and 5 being very difficult, how easy was the cross-reference feature to use?

1	2	3	4	5
[]	[]	[]	[]	[]
Very Easy			Very Difficult	

c. Can you add to that or give an example?

____

____

____

____

6. **Did you use fault isolation diagrams? If YES, then:**

a. Were the diagnostic block diagrams organized correctly?
b. On a scale of 1 to 5 with 1 being very easy, and 5 being very difficult, how easy were the diagnostic block diagrams to use?

1	2	3	4	5
[]	[]	[]	[]	[]
Very Easy				Very Difficult

c. Did the shading of the probable faulty components make sense?
d. Would you change the way the diagnostic system works? How?

____

____

____

____

7. **Did you use the Menu System and Programmable Function Keys? If YES, then:**

a. What data access method did you use more frequently?
b. On a scale of 1 to 5 with 1 being very easy, and 5 being very difficult, how easy were these features to use?

1	2	3	4	5
[]	[]	[]	[]	[]
Very Easy				Very Difficult

c. Which method did you like better? Why?
d. Were any of the functions difficult to understand? Which ones?
e. Would you rename any functions to make them easier to understand?

____

____

____

8. **Did you use the number system and cursor for data selection? If YES, then:**

a. What selection method did you use more: numbers or cursor?
b. On a scale of 1 to 5 with 1 being very easy, and 5 being very difficult, how easy were these features to use?

1	2	3	4	5
[]	[]	[]	[]	[]
Very Easy				Very Difficult

c. Which method did you like better? Why?
d. What method did you prefer for cursor movement: joystick or arrow keys? Why?

____

____

____

____

9. **For the PMA training that you received:**

a. Did the PMA training provide enough information for you to work effectively during the test? Too much/too little?
b. Were there any functions/features that were not trained well enough?
c. After the PMA training, would you feel comfortable teaching co-workers how to use the PMA?

10. **If the electronic form filling function was used:**

a. Were data entries that were made "automatically" by PMA complete and correct?
b. On a scale of 1 to 5 with 1 being very easy, and 5 being very difficult, how easy was the electronic form filling function to use?

1	2	3	4	5
[]	[]	[]	[]	[]
Very Easy				Very Difficult

c. Can you add to that?

II. Ask the following "general" questions of PMA users:

//Alternate asking questions #11 and #12 until you have the three top "likes" and three worst "dislikes" listed.//

11. What did you like most about the PMA system?

1st:____

____

2nd:____

____

3rd:____

____

12. What did you dislike most about the PMA system?

1st:____

____

2nd:____

____

3rd:____

____

13. If you had the choice, would you prefer to use an automated system like PMA or do you prefer to use conventional (paper-based) technical manuals? Why?

____

____

____

____

14. Are there any other maintenance or logistics support functions that you think an automated system like PMA could/should support? If so, please tell me what these support functions might include.

____

____

____

____

15. What changes would you recommend to improve the automatic PMA system?

16. Can you foresee any problems when using an automated system like PMA to perform maintenance duties on the flight-deck/flight-line? If so, please describe to me what these problems would be, and any recommendations you may have for overcoming them.

Thank you very much for your participation. You have provided us with valuable performance data and information on the usefulness of PMA and similar systems. Please wait until this project is finished before discussing any details with your friends. They may be taking part in this project and you could unduly influence them.

THANKS AGAIN!!

APPENDIX F

SAMPLE IETM/PMA FRAMES

VIDS/MAF Showing Discrepancy/Symptom

Block Diagram Screen

Ranked Actions Screen

Log File Screen

Closing Actions Screen

THIS PAGE 134 INTENTIONALLY LEFT BLANK

for reverse of APPENDIX F title page.

After a successful sign on, a representation of the Navy VIDS/MAF form is presented (Fig. 7). This form presents information about the job that the technician needs to get started. The technician can review and enter information required for the form as necessary. The man number, discrepancy, bureau number, date, etc., are included on this form. At the end of the maintenance session, information will be automatically filled in by the software. This information will include maintenance action taken, performance times, how malfunction code, etc.

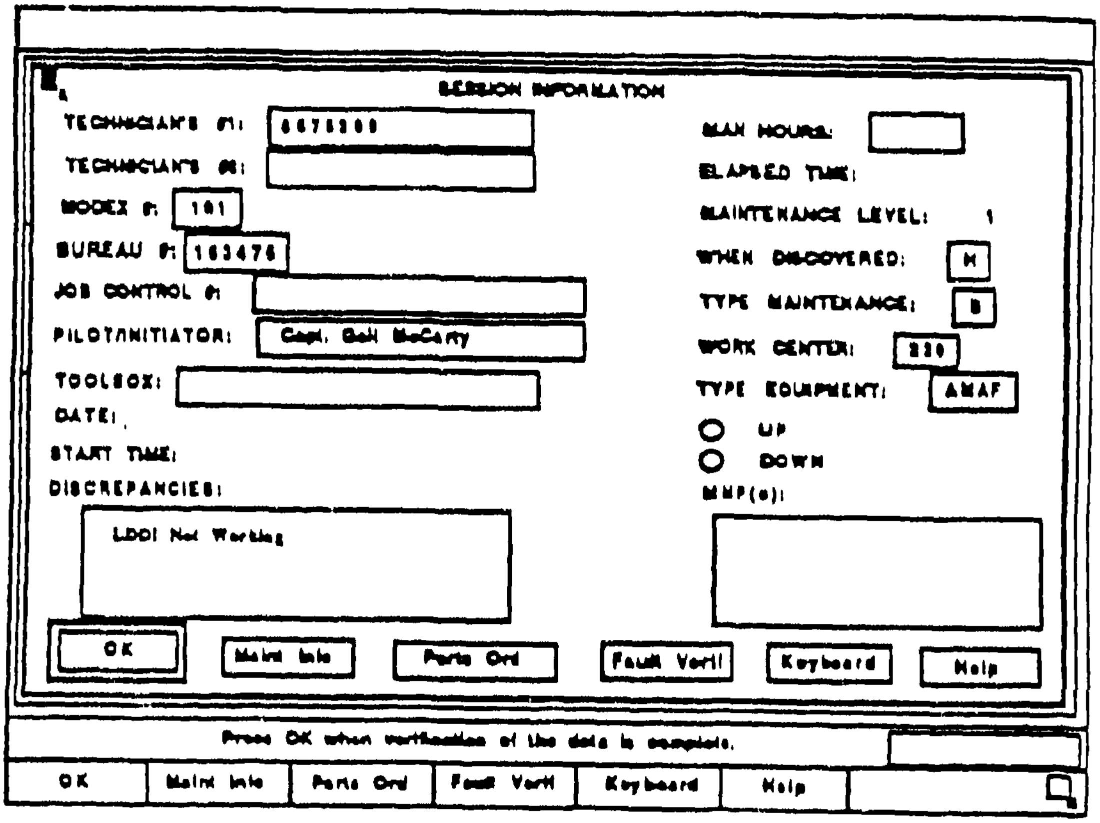


Figure 7. VIDS/MAF Screen.

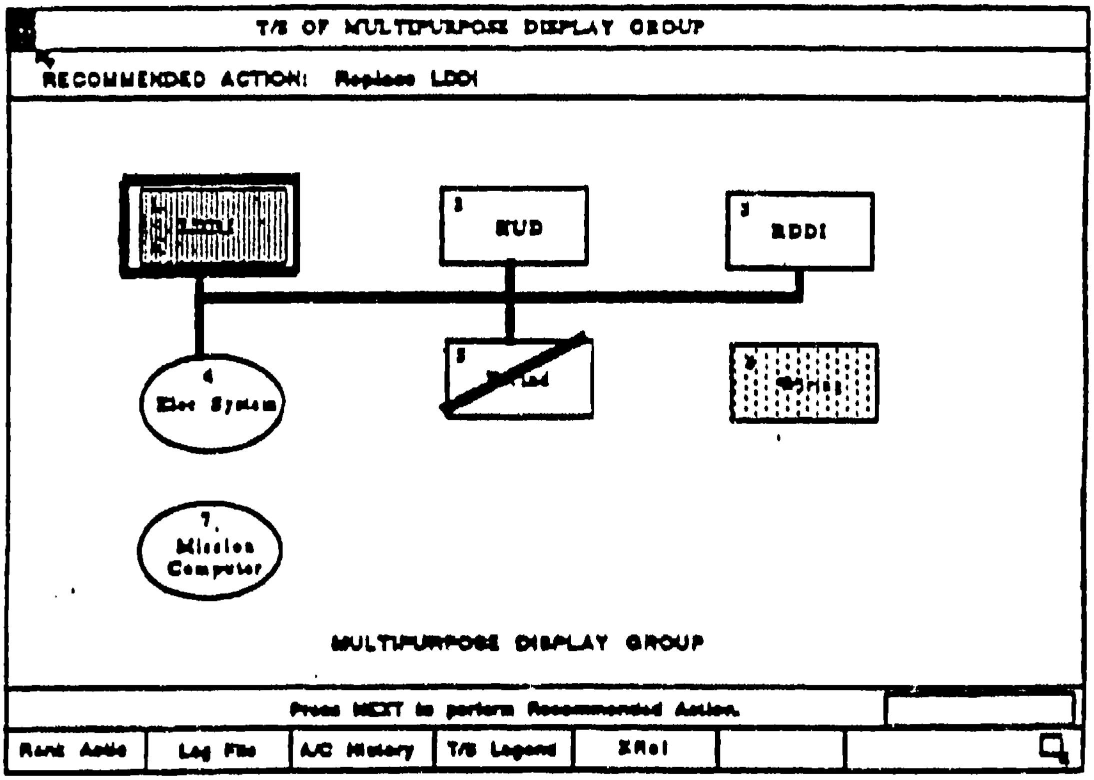


Figure 9. Block Diagram Screen.

The first troubleshooting screen presented to the technician will be an IMIS-DM block diagram (Fig. 9). This encoded diagram aids the technician by conveying the following information: the system undergoing troubleshooting; the recommended (or selected) maintenance activity; the suspected component or system (shaded block); the component or system affected by the activity (dark border around block); related systems (ellipse); and any component or system which have been removed from consideration by some previous action (diagonal through block). Soft keys at the bottom of the screen provide access to additional information the technician may wish to see. After every action (test or repair) the block diagram will be updated to reflect the current status of the component or system.

After reviewing the block diagram, the technician has the option to perform any available action, not just the one being recommended by the IMIS-DM. Several ranked lists are provided to the technician to aid in the troubleshooting process. One such list, Ranked Actions (Fig. 10), provides an interleaved list of additional actions the technician can perform other than the recommended one. Also included on the list are the time required to perform the action, the failure probability of the action, and the availability of each action. The flexibility built into the system allows the user to take full advantage of their experience and knowledge of the aircraft while still being supported by the IMIS-DM.

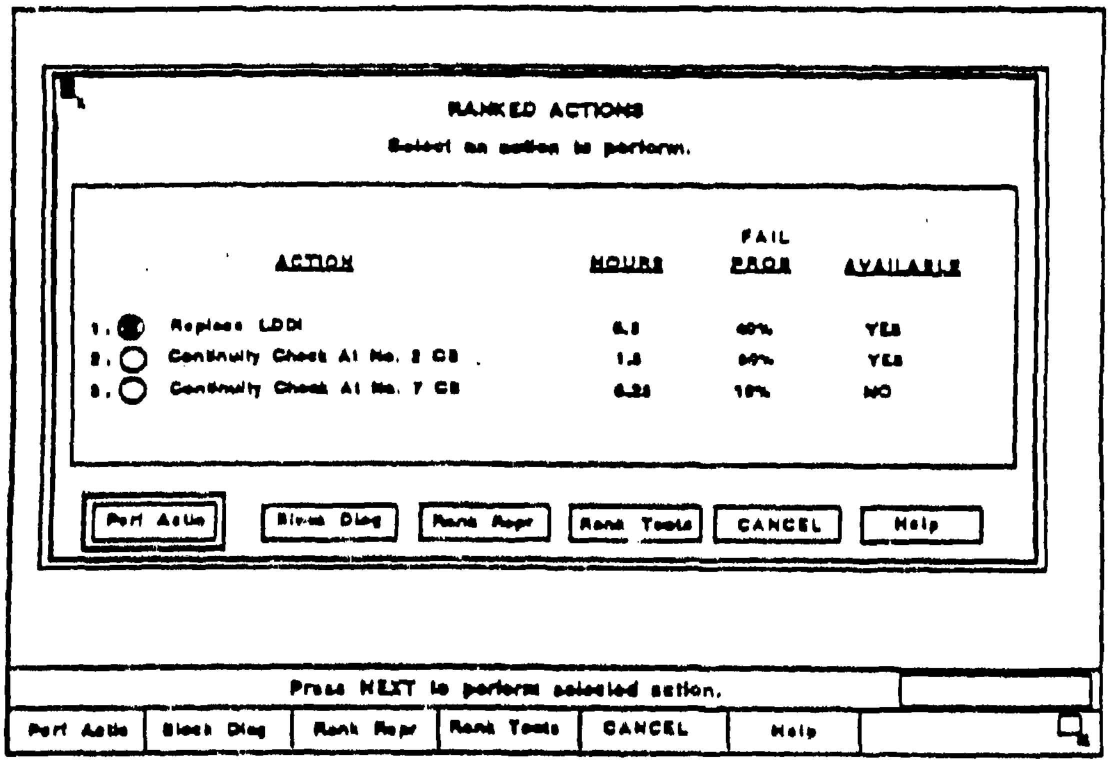


Figure 10. Ranked Actions Screen.

A Log File is maintained during the session (Fig. 14); any time during or after the session, the technician can review the actions they performed and their status.

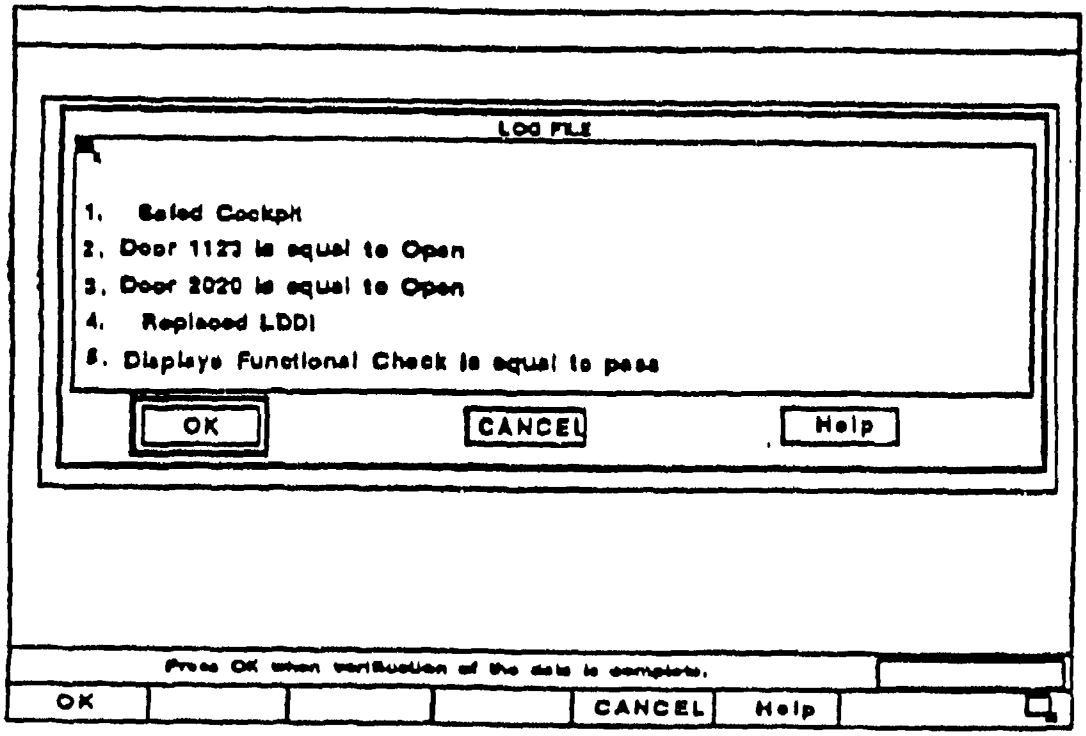


Figure 14. Log File Screen.

When the technician has successfully repaired the aircraft, a list of actions required to close out the session is presented to ensure the aircraft is returned to its proper state (Fig. 15).

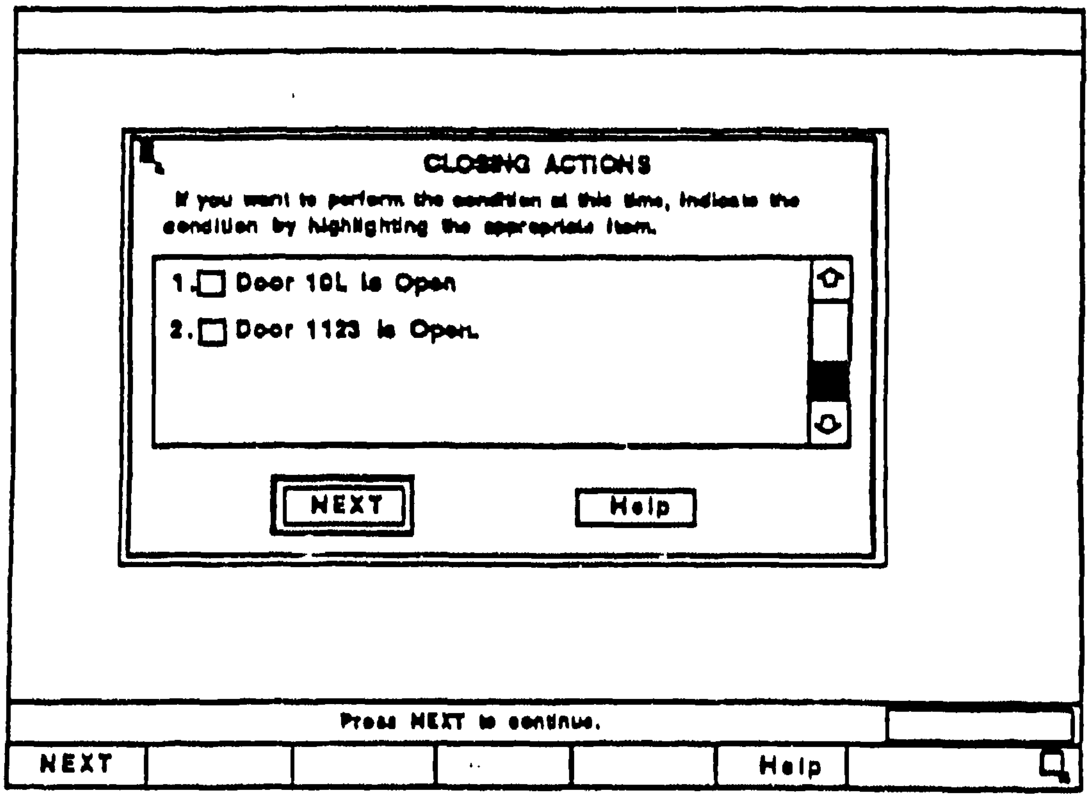


Figure 15. Closing Actions Screen.

THIS PAGE INTENTIONALLY LEFT BLANK

INITIAL DISTRIBUTION

Copies

2 OASD (CEIO)
- 1 W. Gorham
- 1 J. O'Melia

1 DSP–40
- 1 S. Sherman

1 HQAMC
- 1 I. Gaylsh

1 AMC (LOGSA)
- J. Brisson

1 USAMICOM
- S. Pape

2 AFMC (ENC)
- 1 S. Holloway
- 1 G. Zelinsky

7 AL–HRGO
- 1 LT E. Carlson
- 1 D. Gunning
- 1 R. Johnson
- 1 B. Masquelier
- 1 B. Smith
- 1 CAPT S. Smith
- 1 D. Thomas

1 CNO (N43)
- CDR S. Boyce

2 SPAWAR
- 1 22–1B B. Ellis
- 1 222–3 E. Weile

3 NAVAIR
- 1 4114 S. Magill
- 1 4114 C. Janosky
- 1 4114 M. Bare

6 NAVSEA
- 1 SEA–04TD H. Felsen
- 1 SEA–04TD CDR C. Alligood
- 1 SEA–04TDC S. Weinstein
- 1 PMS–400F2 CDR R. Acree
- 1 PMS–400F3 G. Whitsell
- 1 PMS–350L16 M. Volpe

2 NAVSUP
- 1 311B J. DeTolla
- 1 06A CDR N. Wasilewski

1 NAVFAC
- C. Wiber

1 HQMC–A–SL–34
- MAJ C. Mendez

DISTRIBUTION (Continued)

1 NAVELEX DET PTSM
  B. Moyer

1 NSWC–PHD
  W. Honea

3 NATSF
  1 J. Gruden
  1 E. Wolfe
  1 B. Stricker

2 NAWC–AD
  1 CWO J. Monfort
  1 K. Tune

1 NTSC–433
  H. Thorstad

1 CALSRIC
  D. Mockerman

1 CNET
  J. Wyne

1 AEGIS Training Center
  L. Miller

1 MCAS Beaufort
  VMFA 312 CWO W. Murphy

1 NCCOSC
  RDT&E Div.
  Code 433 R. Smillie

12 DTIC

1 V–22
  LT COL T. Bradley

1 Aerospace Industries Association
  W. Balish

1 General Dynamics Land Systems
  C. McClarey

1 General Electric, Lynn
  J. Tilton

2 IBM
  1 J. Crawford
  1 P. Jenkins

1 IDA
  M. Bloom

2 McDonnell Aircraft
  1 R. Jackson
  1 L. Kopek

DISTRIBUTION (Continued)

1 Northrup
J. Bean

1 RJO
T. Reser

1 SEI
J. Jernigan

2 SMA
1 T. Post
1 S. Rainey

3 SRL
1 J. Brainerd
1 C. Normandy
1 C. Magrand

1 TRW
M. Thompson

1 Crew System Ergodynamics Information Analysis Center
L. Quill

2 Westinghouse
1 J. Coviello
1 D. Kniffen

1 General Dynamics Electronics
D. Rose

1 Lockheed Fort Worth
V. Boticelli

CENTER DISTRIBUTION

Copies	Code	Name
1	00	CAPT D. Kruse
1	01	R. Metrey
1	10	CAPT McGaraghan
1	18	A. Camara
5	182	J. Fuller
1	182	R. LeBeau
1	182	E. Jorgensen
100	181	M. Kramer
1	183	J. Garner
1	17	R. Ploe
1	154	W. Nickerson
1	0016	R. Brengs
1	3410	Publications (C)
1	342.1	(C)
1	342.2	(A)
10	3432	Reports Control